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EPA Program Status Report: Oil Shale

Cameron Engineers, Inc, Denver, Colo

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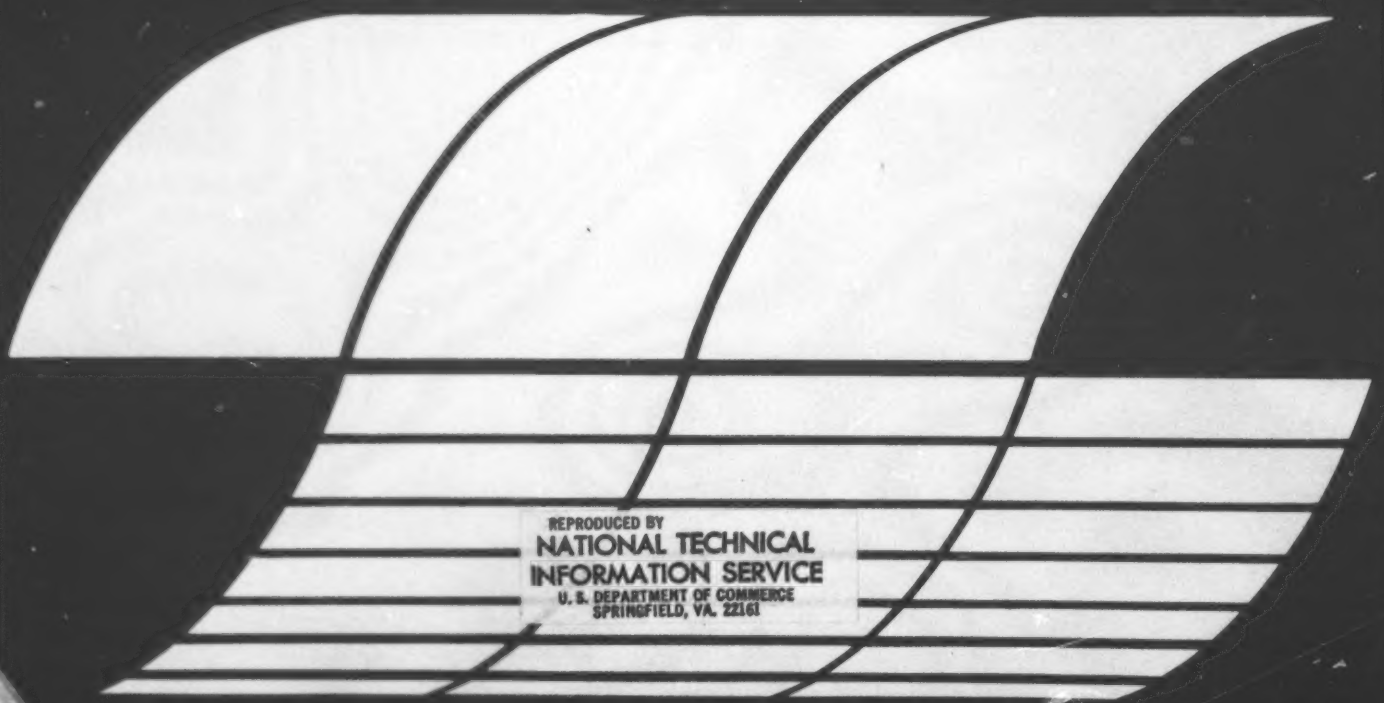
February 1978

EPA PROGRAM STATUS REPORT: Oil Shale

Interagency Energy-Environment Research and Development Program Report



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16. ABSTRACT

This report provides the reader with an overview of current oil shale research and development (R&D) efforts being performed by EPA, or being funded by EPA monies passed-through to other Federal agencies under the Interagency Energy/Environment R&D Program. Chapter 1 introduces the reader to the purpose, background, and rationale behind EPA's efforts; Chapter 2 discusses the EPA program goals and fiscal year 1977 program funding; and, Chapter 3 presents the scope-of-work for 55 ongoing projects. A table at the end of Chapter 3 summarizes these projects by presenting project title, sponsoring agency, performing organization, and project duration.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Assessments Drainage Ecology Ecosystems Environmental Health Environmental Protection Environmental Surveys Fossil Fuels Land Reclamation Mining Monitoring Pollution Resources Management Socioeconomic Factors Synthetic Fuels Tests Water Pollution	Anvil Points Cameron Engineers, Inc. CDM Limnetics Colorado General Electric Green River Formation Parachute Piceance Radian Corp. TOSCO TRW Uintah Utah Wyoming	04B 06P 06A 06T 06C 08H 06E 08I 06F 13B 06J

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EPA PROGRAM STATUS REPORT: OIL SHALE

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FOREWARD

The U.S. Environmental Protection Agency is involved in oil shale research and development through projects for which it provides funds, and in staying abreast of projects funded by other governmental and industrial sources. Research provides data for defining ecological and health effects and for developing cost-effective control technology that can be used by government and industry to minimize degradation of the environment.

This report presents the status of current EPA projects related to oil shale research and development.

ACKNOWLEDGEMENTS

The authors wish to thank Mr. Thomas J. Powers, Mr. Eugene Harris, and Mr. Edward Bates of EPA's Industrial Environmental Research Laboratory in Cincinnati, Ohio; Mr. Terry Thoem of EPA Region VIII, Denver, Colorado; Dr. Dave Coffin of EPA's Health Effects Research Laboratory in Research Triangle Park, North Carolina; and Mr. William N. McCarthy, Jr., Mr. Gerald Rausa, and Dr. Greg D'Alessio of the Office of Energy, Minerals and Industry in Washington, DC for their time and efforts in providing data and review comments for the preparation of this report.

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EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency's (EPA) Office of Energy, Minerals and Industry was established in 1975 to assure that our national energy goals are matched with an effective research and development program in the critical area where energy needs and environmental protection goals overlap. The Office of Energy, Minerals and Industry provides a focus for the EPA's own environmental/energy/industry research and development efforts and also serves as the coordinator of a comprehensive Interagency Energy/Environment Research and Development Program. This program established a mechanism to plan, coordinate, and fund research and development on clean energy use and pollution control technology activities within the participating governmental agencies.

The Office of Energy, Minerals and Industry's oil shale research and development activities are performed by more than a dozen Federal agencies, public and private research institutions, and EPA laboratories.

EPA's Industrial and Environmental Research Laboratory in Cincinnati, Ohio, has been instrumental in leading major research in oil shale development by supporting coordinated, interagency, oil shale efforts through its administration of a research and development program covering environmental assessment and development of extraction and process control technology.

The EPA Health Effects Research Laboratory in Research Triangle Park, North Carolina, is assessing human exposure-effects relationships and is evaluating hazards to man under controlled experimental conditions. Current activity by the Environmental Research Laboratory in Duluth, Minnesota, includes the study of oil shale-related fresh water ecosystems effects. EPA's Region VIII office in Denver, Colorado, is developing a comprehensive information profile for major fresh water aquatic environments that could be affected by oil shale development, and is coordinating air and water monitoring in regional oil shale activities.

Other EPA monitoring research is done at its Environmental Monitoring and Support Laboratories at Las Vegas, Cincinnati, and Research Triangle Park. Las Vegas activities include western regional groundwater monitoring and techniques development, and overhead monitoring. Cincinnati stresses water techniques development and quality assurance. Research Triangle Park is developing energy-related air monitoring quality assurance support and air pollutant measurement and instrumentation research.

EPA is studying the fate in fresh waters, groundwaters, and air of specific pollutants resulting from oil shale development. The Environmental Research Laboratory in Athens, Georgia, is studying the fate of specific pollutants in fresh waters, and the Environmental Research Laboratory in Gulf Breeze, Florida, is assessing carcinogenic compounds that travel by air or water and their effects on the food chain consumed by man.

Federal agencies carrying out work under the Interagency Energy/Environment Research and Development Program with EPA pass-through funds include: the Department of Energy; the U.S. Navy; the National Institute for Occupational Safety and Health; the U.S. Department of Agriculture; the U.S. Bureau of Mines; the U.S. Geological Survey; the National Oceanic and Atmospheric Administration, and the National Aeronautics and Space Administration. Many public and private institutions conduct research and monitoring activities with funds provided by these Federal agencies and the EPA.

In summary, EPA plays an active role in many areas of oil shale research and development. EPA is maintaining a close surveillance on the projects of other Federal agencies in order to preclude duplication and to stimulate active results which can be applied to the technological advancement of oil shale while maintaining the the environmental integrity of the oil shale area.

EPA PROGRAM STATUS REPORT:
OIL SHALE

1. INTRODUCTION

This report provides an overview of current oil shale research and development (R&D) efforts being performed by the Environmental Protection Agency (EPA), or funded by EPA money passed-through to other Federal agencies under the Inter-agency Energy/Environment R&D Program. This chapter introduces the background and rationale behind EPA's efforts. Chapter 2 discusses the EPA program goals and fiscal year (FY) 1977 program funding. The scope-of-work for on-going projects and a table summarizing these efforts are presented in Chapter 3.

1.1 BACKGROUND

Since its establishment in 1970, the EPA has been involved in energy-related environmental research efforts, including the development of pollution control technologies designed to eliminate the adverse effects that are often by-products of energy conversion.

The recent national policy emphasis on development of domestic energy supplies stimulated the formation of an Office of Energy Research (OER) by the EPA in late 1974. The OER was established within the Office of Research and Development (ORD). Reorganization of ORD in June 1975 combined industrial and mineral extraction pollution control research with energy-related environmental research in a new Office of Energy, Minerals and Industry (OEMI).

OEMI provides a focus for EPA's own environment/energy/industry R&D efforts and coordinates the comprehensive Federal Interagency Energy/Environment R&D Program. This program is a seventeen-agency effort whose goals include: environmental protection during every phase of accelerated development and use of energy supplies, with emphasis on domestic resources; and, the development of cost-effective pollution control technologies for energy, industry, and mineral extraction and processing systems.

1.2 RATIONALE

Our cheap and abundant energy supplies are rapidly being depleted. Domestic reserves of oil and natural gas have been declining since 1970, and imported oil and gas are growing increasingly more expensive. Similarly, U.S. vulnerability to supply interruption also increases. By the mid-1980's the U.S. could be vying for scarce oil against its allies and other consuming nations, causing even greater price increases and pressure on the world oil supply.

Consequently, the U.S. must reduce significantly its reliance on imported oil and gas, and make greater use of domestic energy resources. The present energy mix consists of crude oil, natural gas, coal, hydroelectric power, and some geothermal power. There is considerable R&D activity on other energy sources such as solar, tar sands, synthetic oil and gas from coal, and oil shale.

The principal known oil shale deposits of the U.S. are shown on Figure 1. The richest of the large thick deposits is the Green River Formation of Colorado, Utah, and Wyoming. This region contains the largest single known concentration of hydrocarbons in the world. If only that portion of the Green River Formation that contains the equivalent of 25 gallons (or more) of oil per ton of shale were mined, it has been reliably estimated the oil in-place amounts to about 731 billion barrels of oil.

Because western oil shale is a domestic energy resource of considerable magnitude, the availability of large quantities of crude shale oil for refining products such as gasoline, diesel, and jet fuels could sharply expand the U.S. energy supply. Current R&D work is oriented toward finding an economically and environmentally practical way of producing shale oil and bringing it to market.

In utilizing domestic resources, the nation can ill-afford a repetition of the environmental damage which has so often accompanied extraction and processing in the past. Even greater environmental damage could occur under a crash program of energy development unless accompanied by sound environmental control.

The goal of EPA is to ensure that environmental problems are anticipated and evaluated and to develop pollution control measures to hold environmental impacts within acceptable limits.

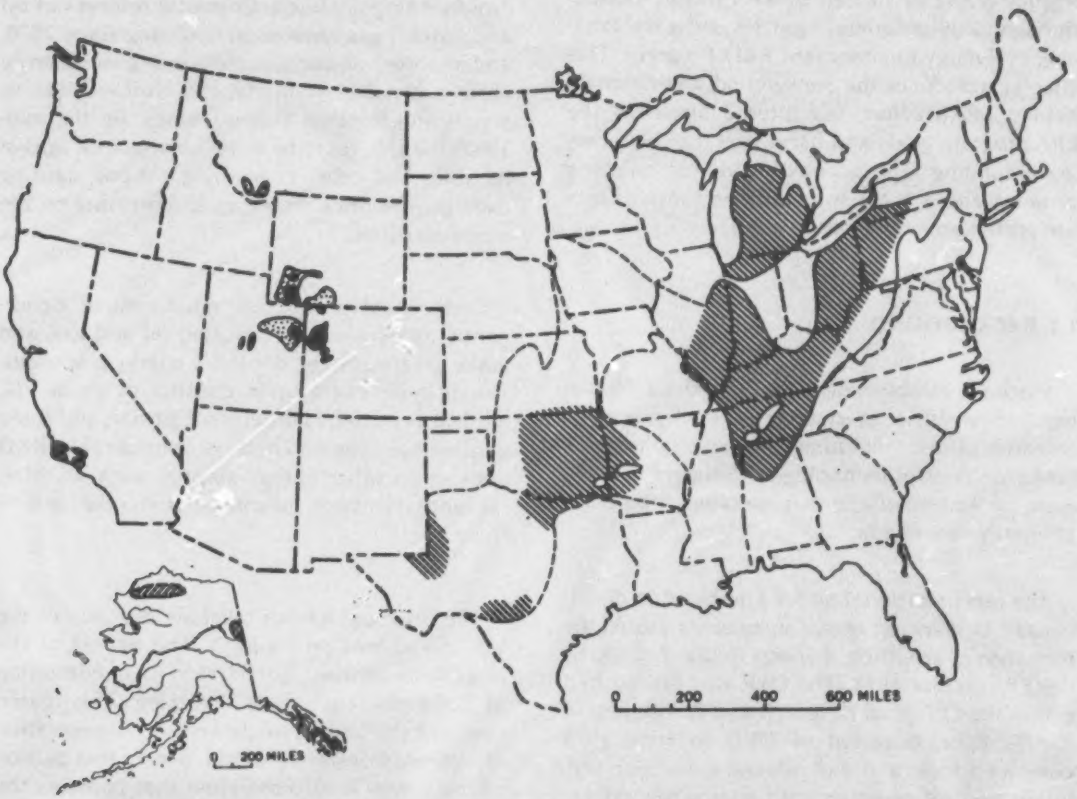


Figure 1.
PRINCIPAL OIL SHALE DEPOSITS OF THE U.S.

Explanation

Tertiary deposits: Green River Formation in Colorado, Utah, and Wyoming; Monterey Formation, California; middle Tertiary deposits in Montana. Black areas are known high-grade deposits.

Mesozoic deposits: Marine shale in Alaska.

Permian deposits: Phosphoria Formation, Montana.

Devonian and Mississippian deposits (resource estimates included for hachured areas only). Boundary dashed where concealed or where location is uncertain.

2. PROGRAM OVERVIEW

EPA's studies of oil shale development are principally supported by funds from the Interagency Energy/Environment R&D Program. The studies provide information on health and ecological effects from pollutants created by the extraction and processing of oil shale. EPA is also developing information on technological methods that can be used to control the release of those pollutants. By working in a closely coordinated effort, EPA and the Interagency Program will allow the oil shale industry to develop in an economically and environmentally sound fashion with the best and most practicable control technologies.

Within EPA, the Oil Shale Work Group (OSWG) is working to assure a coordinated and integrated approach to oil shale R&D efforts. Formed in 1975 by OEMI, the OSWG consists of individuals selected from EPA laboratories and offices who have environmental responsibilities associated with oil shale development. The OSWG provides EPA with technical expertise for up-to-date information on oil shale development and its environmental impacts at the policy/decision-making level. Also, OSWG is responsible for formulating an overall environmental research strategy for oil shale development and for exploring avenues of coordinated R&D operations within EPA and the Interagency Energy/Environment R&D Program. Figure 2 shows the members of the OSWG.

OEMI's oil shale R&D activities are coordinated by EPA, but are performed by more than a dozen Federal agencies under the Interagency Program, public and private research institutions, and various EPA laboratories. The overall effort is divided into four program areas:

- Extraction and Handling
- Processing
- Energy-Related Processes and Effects
- Integrated Assessment

The remainder of this chapter examines each of these areas as they relate to oil shale R&D, and discusses their program funding. Total funding for FY 1977 EPA oil shale efforts is $3,135,900. At the end of this chapter, Figure 3, shows EPA funding and pass-through funding for the oil shale program.

2.1 EXTRACTION AND HANDLING

EPA's program for oil shale extraction and handling attempts to assess potential environmental problems and develop resource handling and control methods for in situ and surface oil shale extraction and land reclamation. This program is needed in order to define environmentally acceptable practices for the extraction of oil shale. The semiarid and arid oil shale areas of the west will be extremely difficult to restore.

Work being performed involves assessing the potential environmental impact upon air and water resources from extraction and handling of oil shale resources. Also included are studies of disposal and revegetation of spent oil shales.

A project is underway to determine the water quality management objectives for surface and subsurface drainage within the oil shale areas of Colorado, Utah, and Wyoming. Two other projects are investigating the surface stability and salt movement in TOSCO, USBM, and Paraho spent oil shales and soil-covered spent shales after a native revegetation has been established by intensive treatments and then left under natural precipitation conditions. The nature, quantities, and specific sources of fugitive dust emissions are being determined in the vicinity of mining operations, haulage roads, crushing operations, and spent shale transfer points. Collection of data is continuing on these projects.

For FY 1977, $305,900 was spent on the oil shale extraction and handling program. Of this, $100,000 was passed-through EPA to the U.S. Department of Agriculture (USDA) for water quality work on surface and subsurface drainage.

2.2 PROCESSING

The EPA program for processing seeks to ensure that future large-scale commercial applications of oil shale processing, combustion, and utilization can be constructed and operated within required environmental limits. The program's approach includes the environmental assessment, evaluation, and testing of a number of processes in order to 1) define the best available control technology, 2) prepare standards-of-practice manuals and 3) support standards setting efforts.

Current work within EPA's processing program involves technical and administrative program support activities to EPA/OEMI to carry out its responsibilities as lead agency for environmental research on oil shale processes. This work includes the maintenance and updating of synthetic fuels documents, support in organizing professional meetings, and consultation on technical problems.

The processing program has sponsored field testing of oil shale surface retorting. Preliminary inorganic and organic water sampling and trace element analyses of retorted shale and raw shale particulates have been made at the Paraho demonstration site at Anvil Points, Colorado, by TRW and the Denver Research Institute (DRI). The objective was to obtain quantitative and qualitative measurements of air, water, and solid compositions and to gain experience which will lead to improved sampling procedures and the determination of priorities for sampling and analysis of shale recovery operations.

Under another contract, TRW and DRI are studying the environmental impacts of oil shale development, and are evaluating the technologies available for the control of air, water, and solid waste emissions.

The FY 1977 budget allocation for the processing program was $638,000.

2.3 ENERGY-RELATED PROCESSES AND EFFECTS

The energy-related processes and effects program is designed to identify the mechanisms of movement within the environment and the effects on human, animal, and plant populations which are associated with energy-related activities. The goal of the program is to compile and evaluate information to support decisions relative to the protection of natural biota, human health, welfare, and social goals. This program includes four areas that are directly involved in oil shale R&D: ecological effects; environmental transport processes; measurement and monitoring, and health effects.

2.3.1 Ecological Effects

The ecological effects research program is inter-related to the results of research conducted in other areas of the Interagency Program. Various methods and instruments developed and refined within the measurement and monitoring areas, and the results of environmental transport processes studies are used to characterize the ecosystem effects associated with oil shale development. The various research efforts determine the effects of organic and inorganic pollutants, thermal discharges and complex effluents on water and land ecosystems.

Current research efforts include the determination of immediate and long-term ecosystem dose-response relationships for single pollutants and combinations of pollutants released by oil shale extraction, conversion, and utilization, and to assess the effects of mining-related transportation systems on water, air, soil, plant, animal, and aesthetic resources.

For FY 1977, $100,000 has been spent on oil shale research through the ecological effects program. Work has been conducted by EPA's Environmental Research Laboratory in Duluth, Minnesota.

2.3.2 Environmental Transport Processes

This research area is closely integrated with the research areas of measurement and monitoring, and ecological effects. Within the former research area, methods and tools are developed,

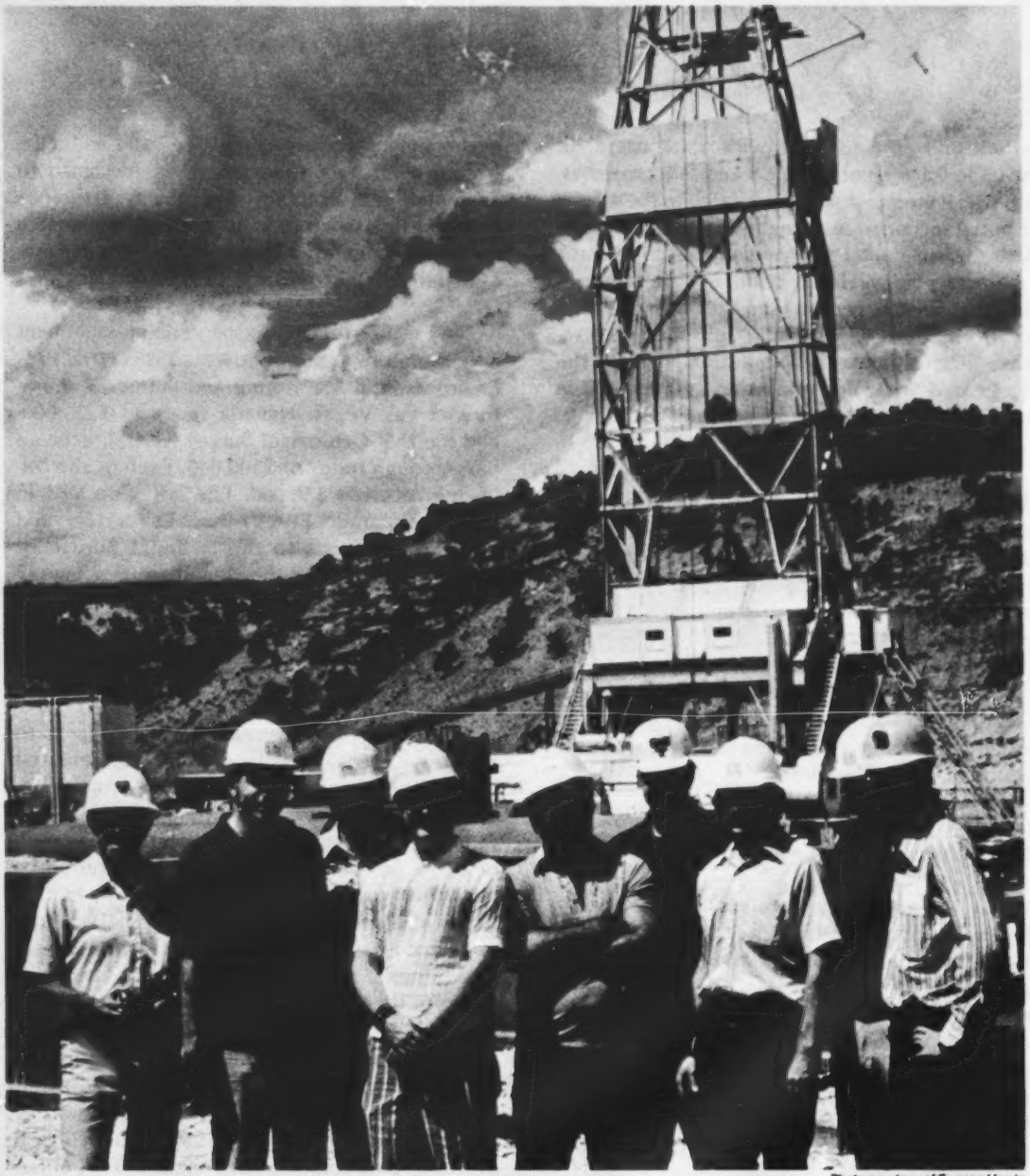


Photo courtesy of Eugene Harris

Figure 2.
THE EPA OIL SHALE WORK GROUP

From left: Edward A. Schuck, EMSL Las Vegas; Terry Thoem, Region VIII Denver; Thomas J. Powers, IERL Cincinnati; William N. McCarthy, Jr., OEMI, Washington, D.C.; Wesley L. Kinney, EMSL Las Vegas; Eugene Harris, IERL Cincinnati; Leonard H. Mueller, ERL Duluth; Atley Jefcoat, IERL RTP; and Edward R. Bates, IERL Cincinnati. The group is standing in front of the Bureau of Mines Big Bore in the Piceance Creek basin. **Members not pictured:** Leslie McMillion, EMSL Las Vegas; Robert Newport, R. S. Kerr Laboratory; Kenneth Biesinger, ERL Duluth; Dr. David Coffin, HERL RTP; Clint Hall, ORD; Ann Alford, ERL Athens; Dr. Dale Denney, RTP; Dr. Norm Richards, ERL Gulf Breeze; Charles Sedman, RTP; Mark Mercer, OSW; John Cunningham, OEM; Robert Thurnau, IERL Cincinnati; Dr. Charles Prien, Denver Research Institute; Alden Christianson, IERL Cincinnati.

tested, and applied to provide data useful in the understanding of transport and fate processes. Ecological effects studies are related to the effects of pollutants on natural organisms and their habitats. Environmental transport processes research addresses energy-related pollutants in terms of mechanisms of dispersion from sites of production, transformations which occur subsequent to release, and ultimate accumulation in man, domesticated and wild animals and plants, and in non-living material such as soil and sediments.

Current efforts are underway to develop methods to predict groundwater changes resulting from mining activity. Presently, the information being generated is in the area of coal strip mining, but the methods will be extrapolated to include oil shale retorting. Efforts in 1978 and 1979 will concentrate on oil shale.

Funding for the environmental transport processes program was $200,000 for FY 1977. Funds went to EPA's R.S. Kerr Environmental Research Laboratory in Ada, Oklahoma.

2.3.3 Measurement and Monitoring

This research area involves the detection, measurement, and monitoring of pollutants, and the performance of quality assurance activities to characterize the ecosystem effects associated with oil shale development. The objectives are to accelerate the development of new and improved sampling and analysis methods for energy-related pollutants and to identify, measure, and monitor energy-related pollutants prior to and during any oil shale development activities.

The measurement and monitoring program is defining baseline environmental conditions and is analyzing the impacts of energy development on the environment by the identification, measurement, and long-term sensing of air, land, and water quality. The various research efforts investigate organic and inorganic pollutants, thermal discharges and complex effluents on water and land ecosystems.

Another important aspect of this program is quality assurance. The data that are collected on environmental pollutants must be valid and reliable, so a separate subprogram was designed to guarantee data accuracy. The quality assurance activities seek to insure that a common acceptable methodology be used by all entities who perform monitoring so that data may be compared.

The FY 1977 funding for oil shale measurement and monitoring projects was $525,000. EPA's Environmental Monitoring and Support Laboratory in Las Vegas, Nevada received $225,000, and the U.S. Geological Survey (USGS) received pass-through funds of $100,000. Each of the following received $50,000: EPA's Region VIII in Denver, Colorado; EPA's Athens Laboratory; and pass-through funds to the National Bureau of Standards (NBS) and the Department of Energy (DOE, formerly ERDA).

2.3.4 Health Effects

The health effects research program seeks to determine the hazards from pollutants released by various energy technologies. The program includes the development of bioassay and other techniques to measure hazards, and the application of these techniques to the characterization of hazards to human health. In relation to human health, the emphasis of the program is on the effects of agents which give rise to carcinogenesis, mutagenesis, teratogenesis, toxicity, and disorders of the cardio-pulmonary system.

A variety of pollutant species are being examined for their impacts on human health. Research efforts have confirmed that pollutants such as sulfur and nitrogen oxides and their atmospheric reaction products are detrimental to human health.

Another major effort has been to assess the potential health impacts of developing energy technologies. Although a number of preliminary assessments have been made, most of the data are derived from processes in the early stages of development. It is acknowledged that standard setting information must be based upon extrapolation of bench or pilot scale data to the commercialization stage. This developmental work also provides guidance to industry on the anti-

cipated environmental regulations in order to avoid sudden and expensive equipment alterations.

Other work involves a number of testing methods that have been developed or refined by research supported by EPA. These efforts include new methods of identification by means of cytological, biochemical, and physiological indicators, of the damages resulting from exposure to pollutants associated with energy development. By incorporating these techniques into a hierarchial testing methodology, EPA's health effects program has been able to efficiently allocate available research funds in the Interagency Energy/Environment R&D Program.

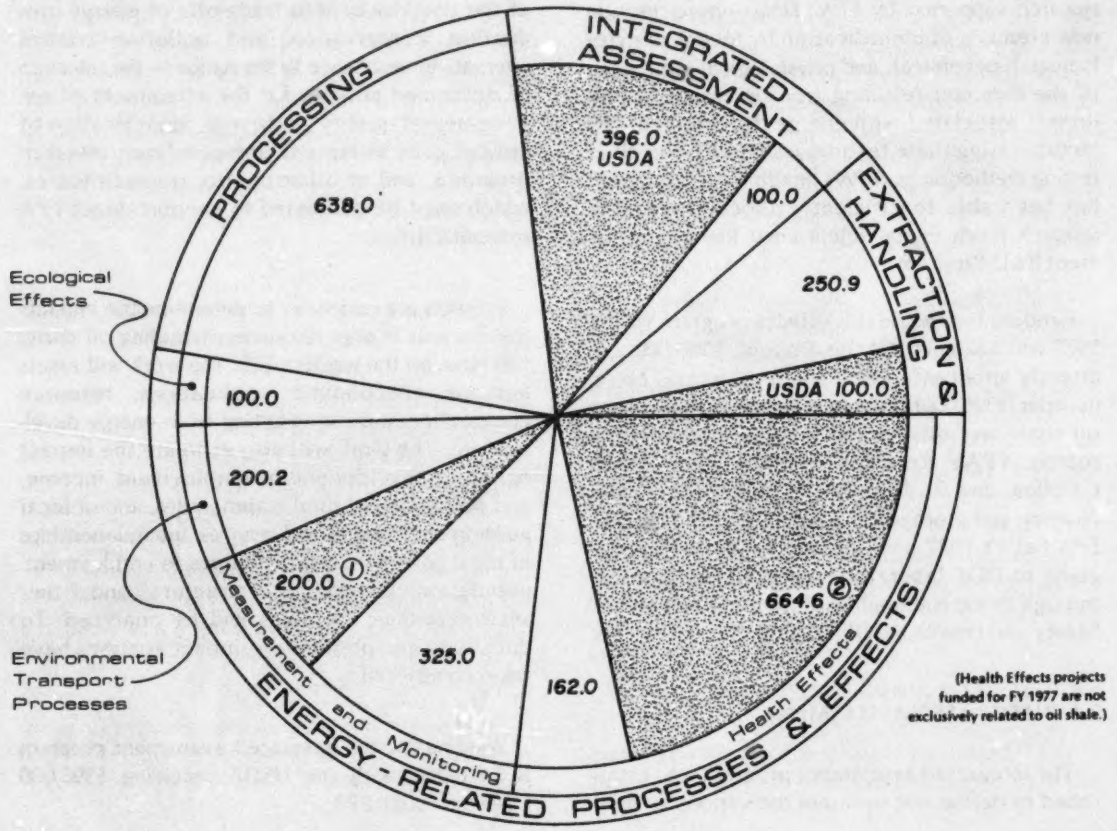
Funding for the health effects program for FY 1977 was $826,600. Of this amount, $500,000 was directly applicable to oil shale projects. The remainder ($326,600) accounted for projects involving oil shale and other fossil fuels in integrated research. EPA's Research Triangle Park, North Carolina, and Gulf Breeze, Florida, Laboratories have on-going programs accounting for $162,000. EPA has FY 1977 pass-through funds of $580,000 going to DOE laboratories, and $84,600 passed-through to the National Institute for Occupational Safety and Health (NIOSH).

2.4 INTEGRATED ASSESSMENT

The integrated assessment program was established to define and evaluate the various environmental and socioeconomic effects which result from energy extraction, processing, transportation, conversion and end use activities. Objectives of the program include: identification of energy supply and conversion alternatives; evaluation of the cost/risk/benefit trade-offs of energy production, conservation, and pollution control alternatives; assistance to the nation in the selection of optimized policies for the attainment of environmental quality goals; and, identification of critical gaps in current energy-related research programs, and of other priority research topics, which must be addressed to support direct EPA responsibilities.

Projects are underway to determine the impacts that various energy resources, including oil shale, will have on the western U.S. The work will assess agricultural-economic implications, resource competition and use resulting from energy development. The work will also estimate the impact of energy development on employment, income, and population of rural communities, and of local government finances and services. Interrelationships of local government expenditures to employment, population, income, age structure, and other socio-economic variables will be analyzed. To date, data and preliminary impact analyses have been completed.

Funding for the integrated assessment program is $496,000, with the USDA receiving $396,000 passed-through EPA.



(Health Effects projects funded for FY 1977 are not exclusively related to oil shale.)

▩ Pass—Through Funds

Total Funding: 3,135.9 K

① funds passed through to:
U.S. Geological Survey - 100.0 K
National Bureau of Standards - 50.0 K
Department of Energy - 50.0 K

② funds passed through to:
National Institute for Safety and Health - 84.6 K
Department of Energy - 580.0 K

Figure 3.
EPA OIL SHALE FY 1977 FUNDING SUMMARY
(in thousands of dollars)

3. CURRENT PROGRAM STATUS

Each EPA funded project falls under a category described in Chapter 2 of this report. The same is true for projects supported by EPA pass-through funds. Table 1 on page 27 summarizes the status of EPA's current oil shale program.

3.1 EXTRACTION AND HANDLING

Within the extraction and handling program are three projects sponsored by EPA's Industrial Environmental Research Laboratory in Cincinnati (IERL-CIN), and being performed by Colorado State University, Fort Collins, Colorado. These projects deal with surface stability, water movement and runoff, water quality, and revegetation of processed oil shale. A similar complimentary project is being conducted by the USDA using EPA pass-through funds. Another study is being conducted by TRW, Inc., Redondo Beach, California, which analyzes the mining and handling operations and the fugitive dust emitted at the Paraho site in Colorado.

Technologies for Controlling Adverse Effects of Mining on Forest, Range and Related Freshwater Ecosystems

Coordinated studies are underway to develop technologies for controlling adverse effects of mining on forest, range, and related freshwater ecosystems. The studies are being conducted by USDA Forest Service research scientists at several locations in the Northern Great Plains and Southwest U.S., by the Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado; the Intermountain Forest and Range Experiment Station, Ogden, Utah; the Forest Environment Research Staff, Washington, D.C., and the Northeastern Forest and Range Experiment Station, Upper Darby, Pennsylvania.

The work will: (1) develop guidelines and criteria for overburden drilling, analysis, and placement as related to growth-supporting media; (2) prepare technical handbooks on revegetation recommendations for new research; (3) develop guidelines and criteria for the use of non-mine wastes as soil amendments on oil shale spoils, and (4) develop recommendations, guidelines, and criteria, based on new research for revegetation following oil shale mining. This project is sponsored by USDA with pass-through funds from EPA. Term of the contract is from 1975 to 1979.

Water Quality Hydrology Affected by Oil Shale Development

Colorado State University is under a grant from IERL-CIN to study the water quality of both surface and subsurface drainage within the oil shale areas of Colorado, Wyoming, and Utah. Specific objectives of this study are to: (1) gather all available data pertinent to the present and future assessment of the water quality hydrology in the oil shale regions of the Upper Colorado River basin; (2) summarize and analyze these data in order to identify data deficiencies, needs for additional data, and procedures for the assessment of the impact on water quality management, and (3) develop procedures for the quantitative assessment of the quantity and quality of surface and subsurface runoff from processed shale residue and mine spoils, and to verify these procedures on a field scale.

Term of this project is from June 1975 to June 1978. Consideration is being given to extending the contract to June 1980.

Fugitive Dust from Oil Shale Extraction

TRW, Inc., is working under contract to IERL-CIN to obtain samples of fugitive dust generated at the Paraho shale oil operations at Anvil Points, Colorado. Support services and facilities have been worked out with the site operator, Development Engineering, Inc., Grand Junction, Colorado.

The nature, quantities, and specific sources of fugitive dust emissions were determined in the

vicinity of mining operations, haulage roads, crushing operations, and spent shale transfer points. A survey was made of the mining and oil shale handling operations, to determine the sources of fugitive dust, and candidate locations for collection devices. Visual observations of dust-generating operations and local wind behavior was useful in preparing the equipment plan and choice of methodology.

The principal dust collection devices were high-volume samplers. The samplers had cumulative timers and included a means of operating only when the wind direction was in the range identified with a particular sampler. These were supplemented by cascade impaction samplers for determining particle size distribution. Testing locations and periods of operation were reviewed to obtain concurrence and assure that mining and extraction operations were not affected by the sampling activity. Meteorological instrumentation was also provided at each collection location to record wind direction and velocity continuously.

As in most mountain valley terrains, there is a strong upslope wind during midday, and downslope wind in the evening and early morning hours. However, local wind patterns may vary, so that close surveillance was required to determine when a collector was in an upwind or downwind position. The actual location of any collector was variable with respect to a fugitive dust source, depending on how much of a sample catch is needed. Sampling sites were worked in sequence, to utilize limited meteorological stations.

The period of sampling varied, depending on the amount of sample desired and proximity to a source. The cascade samplers were used for dust collection and size analysis during two separate two-week test periods, since high-volume samplers needed to be separated in the laboratory.

Records of mine and plant activity for each sampling site were kept by the field crew. In particular, mining activities, blasting, haul-truck operations, crushing, and shale transfer operations were logged, since all of these activities are intermittent or variable. These records were coordinated with the high-volume unit records.

The values determined for each upwind sampler were used as a baseline to determine the relative increase of particulates from a source as measured by corresponding downwind samplers. The adjusted measurements from the nearest and the farthest downwind samplers were extrapolated to estimate the possible source emission levels. The extrapolation was only a rough estimate, because modeling of particulates exceeded the scope of work.

At present, all data have been collected, sample analyses are being run, and data are being interpreted. A final report on data monitoring is expected in March 1978.

Vegetative Stabilization of (TOSCO and USBM) Spent Oil Shales

Colorado State University is working under grant to IERL-CIN to investigate surface stability and salt movement in spent oil shales and soil-covered spent shales after a cover of native vegetation has been established by intensive treatments and then left under natural precipitation conditions. Observations on vegetation, moisture, salinity, runoff, and sediment yields were conducted from 1974 to 1978, with work expected to continue through July 1980.

The study is being performed on two different spent oil shales – course-textured (USBM) and fine-textured (TOSCO). Various soil treatment tests were conducted to study plant establishment on: (1) leached and fertilized soil over unleached spent shale; (2) six inches of soil over leached spent shale; (3) one foot of soil over unleached spent shale, and (4) soil.

A good cover of native species was established on all plots by leaching, fertilization, seeding, mulching, and irrigation. The plots, which have not been irrigated since they were established, now support an adequate cover of vegetation dominated by perennial grasses with the exception of low-elevation TOSCO plots which are dominated by a mixture of annuals and perennial grasses.

Water applied during leaching and establishment was being used by plants during their third

growing season. Resalinization occurred following leaching of the fine-textured TOSCO spent shale and salt moved up into six inches of soil cover over leached TOSCO spent shale. The USBM spent shale was resalinized at the high-elevation site following inadequate leaching, but was not resalinized at the low-elevation site. The 12 inches of soil cover over the unleached spent shale was not salinized at either study site.

The greatest runoff was from the TOSCO spent shale. Runoff was moderately to highly saline. The sodium adsorption ratio was low for all runoff. Sediment yields were very low reflecting the use of mulch and establishment of adequate plant cover.

Work to be accomplished for the 1977 to 1978 year includes: moisture readings of plots; collection and summarization of data taken during the summer of 1977; general observations and collection of runoff and sediment samples; soil moisture measurements and maintenance of meteorological equipment; vegetation analysis of species and ground cover, and the analysis of data in a written report. The 1977 to 1978 work will be of particular interest because the data will show information on the oil shale plots as influenced by the severe drought that has prevailed in western Colorado.

Vegetative Stabilization of Paraho Spent Oil Shale

Colorado State University is working under grant to IERL-CIN to study surface stability and water movement in and through Paraho spent shale and soil-covered Paraho spent shale. In addition, the distribution of water and salts in the plots will be monitored with the objective of quantifying the potential salt pollution from shale residues. These data will be used to develop and verify a mathematical model of salt and water transport, and to estimate the long-term water quality and quantity aspects of large scale disposals of spent shale residues.

This study attempts to duplicate, on a small scale, what might be disposal schemes for Paraho spent shale. This project involves the compaction of a 3-foot layer of Paraho spent shale over a reinforced concrete pad (132 feet long, 44 feet wide, six inches thick, and coated with an inert sealant). A 4-inch thick layer of gravel is placed immediately over the concrete pad. This allows collection of water which may percolate through the compacted spent shale. Figure 4 shows an experimentation plot.

A layer of uncompacted spent shale (varying in depth from 3 to 5 feet) is placed on top of the compacted shale (96 to 100 lbs/ft^3). The uncompacted shale then is covered with either 8, 16 or 24 inches of soil.

Two separate concrete pad units with the above treatments have been constructed on Bureau of Land Management property just below the housing area of DOE's Anvil Points Oil Shale Research Facility. One unit is used to simulate a low-elevation spent shale disposal site, while the other is used to simulate a higher elevation site receiving more precipitation. Since the actual study site is located in the low-elevation zone, the high-elevation disposal zone is being simulated with irrigation. The low-elevation unit was irrigated the first growing season to establish the vegetation; in later years it will be left under natural precipitation. The high-elevation unit requires yearly irrigation, the schedule is made up to simulate a a disposal site at 8,000 feet with 20 inches of average annual precipitation.

To develop the hydrological model phase of this study, drains were installed in the surface of the concrete pad and at the interface between the compacted and uncompacted zones. The purpose of the drains is to collect the water and salts percolating through the zones. In addition to collecting the percolate, the surface runoff from each treatment has been collected.

Data collection and monitoring are continuing. Term of this contract is continuing from July 1975 to July 1978.

3.2 PROCESSING

Two projects, within the processing program, are being conducted by TRW, Inc., and the Denver

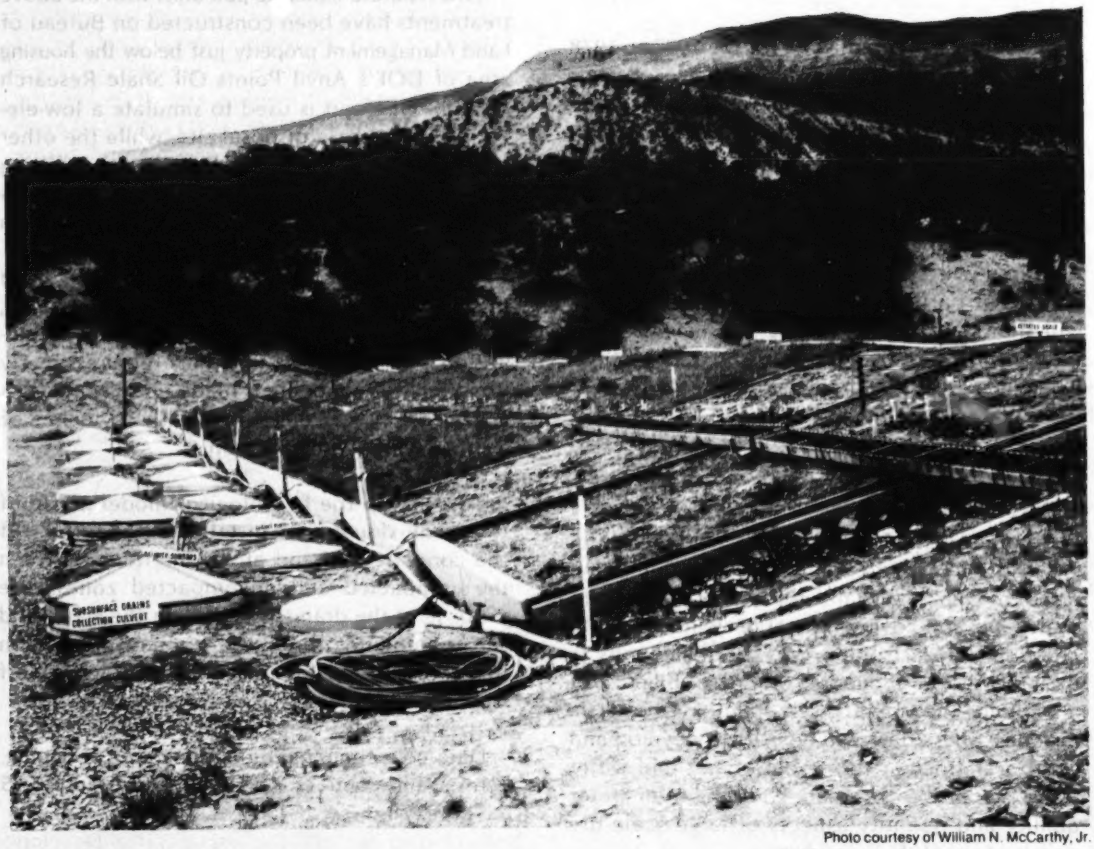


Photo courtesy of William N. McCarthy, Jr.

Figure 4.

SHALE DISPOSAL TRANSPORT AND EFFECT EXPERIMENTATION PLOTS, ANVIL POINTS, COLORADO.

Left Center: Water collection reservoirs. **Center:** Plots showing the variation in vegetation due to different depths of soil cover and aspects.

Research Institute (DRI). TRW/DRI are collecting background data on shale recovery processes and reserves, and are conducting a comparative assessment of their environmental acceptability via the control of air, water, and solid waste emissions. One other project being conducted by Cameron Engineers, Inc., Denver, Colorado, provides program support in synthetic fuels development to OEMI.

Environmental Impact of Oil Shale Development

TRW/DRI are working under contract to IERL-CIN to study the environmental impact of oil shale development. This three-year project, scheduled to end in May 1978, includes the acquisition of the necessary background data on the principal industrial shale recovery processes and U.S. shale resources, a comparative assessment of their environmental acceptability, and an evaluation of technologies available for the control of air, water, and solid waste emissions.

Work under this contract was divided into six tasks: (1) project management; (2) oil shale and recovery process characterization; (3) engineering analysis and problem definition; (4) field testing and laboratory analysis; (5) environmental evaluation, and (6) evaluation of existing environmental control technology. This project has provided a a basis for establishing rational design, management, and monitoring procedures to mitigate unavoidable adverse environmental impacts prior to development of a full-scale oil shale industry.

During the period beginning June 1975 and ending August 1977, 20 reports were prepared under this contract. These reports are listed in Appendices D and E.

To date, the only report which has been released for publication under this contract is; "A Preliminary Assessment of the Environmental Impacts from Oil Shale Developments," EPA-600/7-77-069, July 1977. The report summarizes the status of oil shale technologies and development activities, the nature and sources of pollution from oil shale development and their potential impacts on the physical environment. This information has been collected from related ongoing industrial and government activities to provide a consolidated data source for planners and researchers concerned with oil shale development, to identify data and research gaps so that priorities for subsequent efforts in this area can be defined, and to establish the baseline material from which future environmental assessments can be made and related pollution control methods can be developed. The other reports are expected to be released in late 1978.

Sampling and Analysis of the Paraho Surface Retort

A sampling and analysis research program at the Paraho oil shale retorting demonstration site at Anvil Points, Colorado, is being conducted by TRW/DRI in conjunction with DOE's Laramie Energy Research Center (LERC), Development Engineering, Inc., Grand Junction, Colorado, and EPA's IERL-CIN. The overall objective of the test program is to obtain quantitative and qualitative measurements of air, water, and solid compositions, and to gain experience that will lead to improved sampling procedures and the determination of priorities for sampling and analysis of oil shale recovery operations. In addition to preliminary sampling and analysis which has recently been completed, a more extensive program is planned to follow in 1978.

The Paraho demonstration site is presently the only surface retorting operation on-going within the U.S. Figure 5 shows the Paraho plant at Anvil Points. The existing Anvil Points facility includes two vertical retorts: a larger semi-works unit in which a portion of the off-gas was recycled and heated externally to supply heat to the retort and a smaller pilot plant in which air was introduced with recycle gas to support combustion of carbon on retorted shale as a source of process heat. The test plan included both retorts, as their process streams are different. Selection of sample locations was based on a need for information on process streams relative to emissions and effluents expected in a full-scale plant.

Samples taken included the recycle gases, recycle condensate, product oil/water, processed shale discharged from the retorts, and dust in the vicinity of crushing, screening, and conveying equipment. A variety of analytical methods was

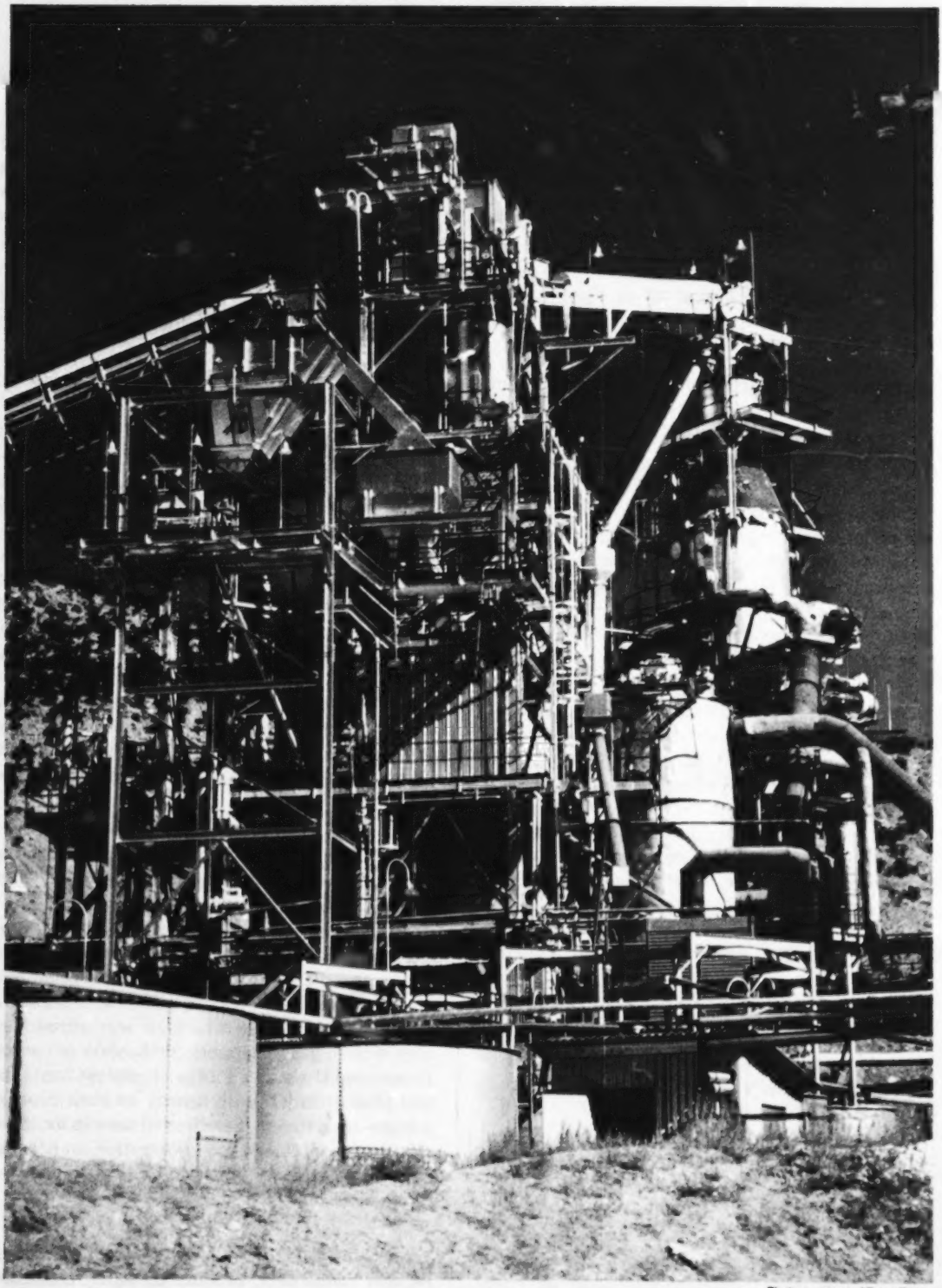


Photo courtesy of Terry Thoem

Figure 5.
PARAHO SURFACE RETORT, ANVIL POINTS, COLORADO

used, including wet chemical analysis, spark-source mass spectrometry, high-pressure liquid chromatography, thin-layer chromatography, gel permeation chromatography, and gas chromatography/mass spectrometry methods.

Condensate water inorganic analyses were done for calcium, magnesium, sodium and potassium salts, ammonia, gross parameters, and trace elements. Condensate and product water samples were also analyzed for organic neutrals, organic acids, and organic bases. Elemental determinations of both retorted shale and raw shale particulates were made.

This project is being conducted as part of the environmental impact of oil shale development program previously discussed. Term of the contract is from 1975 to 1978.

Program Support in Environmental Assessment and Control Technology Development for Advanced Fossil Fuels

Cameron Engineers, Inc., Denver, Colorado, is providing technical and administrative assistance to EPA/OEMI to support its responsibilities as lead agency for environmental research on energy processes. In particular, Cameron Engineers is working on environmental assessment and control technology development for advanced fossil fuels conversion techniques, including high and low-Btu coal gasification, coal liquefaction, residual oil gasification, and oil shale retorting. Specific objectives include maintaining and updating documents on environmental problems and R&D programs, producing and maintaining a system for describing R&D options and setting priorities among the options, providing administrative and technical support for short term assignments, such as reporting on professional meetings, and consultation on specific technical problems. Term of the contract is from October 1976 to October 1978.

3.3 ENERGY-RELATED PROCESSES AND EFFECTS

The energy-related processes and effects program is designed to identify and assess the environmental effects of each stage of an energy source's fuel cycle. The program is subdivided into four major areas: ecological effects; environmental transport processes; measurement and monitoring, and health effects. Current oil shale R&D activities for each of these areas are presented in the following sections.

3.3.1 Ecological Effects

Toxic Effects on the Aquatic Biota from Coal and Oil Shale Development

The Environmental Research Laboratory in Duluth (ERL-Duluth), is providing predictive information with regard to potential toxicants to the aquatic environment resulting from coal and oil shale extraction and conversion. Current work involves bioassays of retort process waters from the Paraho project, and chemical and analytical studies of water in the Piceance Creek basin. Term of the contract is from 1975 to 1978.

3.3.2 Environmental Transport Processes

The Mineralogy of Overburden as Related to Groundwater Chemical Changes in Strip Mining of Coal, In Situ Coal Gasification, and Oil Shale Retorting

In the course of this study, overburden cores and groundwater samples, will be chemically and physically characterized. It is anticipated that this effort will generate scientific information, predictable in nature, which can be extrapolated to other areas of mining activity. The overall objective of this research is to provide regulatory agencies and the mining community with a method to predict groundwater changes resulting from coal strip mining, in situ coal gasification, and oil shale retorting. This is a four-year effort, in which the third year will concentrate on oil shale, with a report expected in 1979. The EPA Robert S. Kerr Environmental Research Laboratory in Ada, Oklahoma is conducting this project. Term of the project is from 1975 to 1979.

3.3.3 Measurement and Monitoring

Projects under the measurement and monitoring program deal with air, surface, and groundwater

monitoring and methodology development, instrumentation development, and identification of wastes and effluents. Work is being conducted by EPA's Environmental Monitoring and Support Laboratory in Las Vegas (EMSL-LV), the Region VIII office in Denver, the Environmental Research Laboratory in Athens (ERL-Athens), USGS, DOE, and NBS.

3.3.3.1 Air Monitoring

Oil Shale Area Meteorological Data Analysis

CDM Limnetics, Wheat Ridge, Colorado, has purchased upper air meteorological data from the National Climatic Center in Asheville, North Carolina, for the National Weather Station at Grand Junction, Colorado. The temperature, wind speed, and wind direction data collected at Grand Junction, Colorado has been compared with like data obtained near the Colorado Federal oil shale lease tracts. A determination of the representativeness of obtaining upper air data for 15 days in the central portion of each quarter has been made. A report providing this low level radiosonde monitoring data comparison has been released. This project was sponsored by EPA, Region VIII, Denver, Colorado. The project was completed.

Air Quality and Surface Wind Monitoring in Colorado

The Colorado Department of Health is under contract to EPA Region VIII to install and operate air monitoring sites in selected areas of western Colorado to collect baseline data prior to major expansion of energy activities. Particulate samples from the energy area are analyzed for nitrate and sulfate content. EPA Region VIII is administering this project with OEMI funds. Term of the contract is from 1975 to 1977.

Upper Air Meteorological Data Collection

Aeromet, Inc., Norman, Oklahoma, has collected upper air data at tracts C-b and Ua/Ub from June 1, 1976 through October 30, 1977. Temperature, wind speed, and direction versus altitude were measured via pilot balloons and temperature sondes. Temperature and wind data were used to generate stability-wind rise data on a seasonal, annual, and monthly basis. These data also provided mixing height data. EPA Region VIII is administering this project with OEMI funding. Term of the contract is from 1976 to 1978.

3.3.3.2 Groundwater Monitoring Methodology Development

Monitoring the Impact of Western Coal Strip Mining and Oil Shale Extraction on Groundwater Quality

General Electric - TEMPO, Santa Barbara, California, in conjunction with the University of Arizona, Department of Hydrology, is studying the effects of the oil shale extraction and processing operations on groundwater quality in the vicinity of the Uinta basin of northeastern Utah, through a carefully designed and systematically executed monitoring program. The monitoring program design is based on the identification of existing program deficiencies and/or the inventory of potential sources and causes of groundwater pollution. A final report will be prepared on the results of the research and monitoring effort and will serve as a guide in the design and operation of groundwater quality programs for other mining locations. This project is being sponsored through EPA's EMSL-LV. Term of the contract is from September 1976 to September 1981.

Energy-Related Water Monitoring Data Integration

EPA's EMSL-LV is establishing a water monitoring network throughout the western U.S. to monitor and assess the impact of energy resource development. Through the use of computer data banks, water monitoring stations that are currently in operation, and those prior to 1970 which have reported a large number of measured parameters were selected for incorporation into a primary monitoring network. Parameters of interest were identified and a quality assurance program is being established in participating laboratories. Data from the primary network stations are being augmented with data from other stations. An assessment of baseline water quality, trends, and impacts on a basin-by-basin basis is underway. As data gaps

are identified, actions will be taken to correct them. The primary net will be updated periodically and extended into areas not presently addressed. Term of the contract is from 1975 to 1980.

3.3.3.3 Water Monitoring

Water Quality and Geochemistry of Shallow Aquifers of Piceance Creek, Colorado

The USGS, Lakewood, Colorado, is collecting detailed chemical analyses of the relatively shallow groundwaters that may be affected by mining oil shale and associated minerals, principally in the Piceance and Yellow Creek basins of Colorado. The study serves to support a portion of an initial effort to improve predictive geohydrologic and chemical models that may better evaluate the impact of oil shale mining on the hydrologic regime of the Piceance Creek basin. The total effort is designed to develop the data base and analytical capability required to make evaluations. The existing state of chemical equilibrium will be documented and water quality will be studied to predict effects of dewatering on water chemistry.

Chemical analyses of water from 10 wells and 48 springs were analyzed and are being used to identify the source and distribution of major and minor ionic species in the Green River Formation. Data are being compiled and analyzed for use in constructing a profile-oriented solute transport model. This project is sponsored by USGS with pass-through funds from EPA. Term of the project is from 1975 to 1980.

Water Quality Monitoring on White River, Parachute Creek and Logan Wash in Oil Shale Areas of Western Colorado

The USGS, Lakewood, Colorado, is collecting detailed water quality data from selected surface waters in the areas of western Colorado likely to be affected by oil shale development. The study has initiated several new water quality monitoring stations and supplements the parameter coverage at several existing baseline water quality conditions in the oil shale areas so that possible future effects of oil shale development can be evaluated.

There are two existing USGS monitoring stations located upstream and downstream from the Federal oil shale leases on the White River; these stations will be supplemented for additional parameter coverage. The Parachute Creek station, established between two different oil shale projects and upstream from major irrigation diversions, will provide baseline water quality data and monitor future impacts from oil shale development. The station at Logan Wash will provide baseline data for evaluating the water quality impacts of in situ oil shale development in that specific drainage. Stream flow water quality monitoring equipment has been acquired for the Parachute Creek and Logan Wash stations. This project is performed by USGS with pass-through funds from EPA. Term of the contract is from April 1975 to October 1980.

Collection of Geochemical Data in the Piceance Creek Structural Basin of Colorado

The USGS, Lakewood, Colorado, is monitoring the collection and analysis of geochemical data on the relatively shallow groundwaters that may be impacted by the extraction of oil shale in the Piceance and Yellow Creek basins of Colorado. Water samples are collected from approximately 12 wells and many springs. Chemical analyses for approximately 30 parameters are being collected on selected samples. Data will be used to refine predictive models of resultant water quality both for those waters encountered by mining operations and waters centering surface drainages and springs and seeps. USGS is being funded by EPA pass-through funds. Term of the contract is from 1976 to 1978.

Potentiometric Surface of Shallow Aquifers in Piceance Creek Structural Basin

The USGS, Lakewood, Colorado, is developing a calibrated digital model to predict the effect of oil shale development on the hydrologic system. This development will be accomplished through the drilling and completion of test wells. The data will be used to improve the calibration of an existing digital model of the system. Progress has included the preparation of drilling specifications, a contract award, and the successful

completion of 22 observation wells. The total footage drilled was 25,092. Water temperature and specific conductance data, water samples for chemical analysis, and discharge rate measurements were obtained from each well. A basic data report will be prepared which will summarize the data collected during drilling of the observation wells. USGS received EPA pass-through funds on this project. Term of this contract is from 1975 to 1978.

3.3.3.4 Instrumentation Development

Instrumentation and Methods for Characterizing Aqueous Effluents from Oil Shale

DOE is studying the feasibility of large scale oil shale processing in the Green River Formation. Plans include surveillance of related effluents. This project focuses on the development of methods for the chemical characterization of aqueous effluents associated with the retorting processes. Attention is being given principally to organic and trace metal components. Organic components are being analyzed by several methods under development. Major organic components are analyzed directly by gas chromatography with no sample pretreatment. Minor and trace organic components are removed from the samples by adsorption on activated carbon, neutral macroreticular resins, and ion exchange resins. The components are profiled by gas chromatographic methods employing standard and specific element detectors. Fractionation of the organic mixture is followed by identification and quantification of some nitrogenous bases. Trace metals will be determined simultaneously by spark source mass spectrometry. This project is being conducted by DOE with EPA pass-through funds. Term of the contract is from 1976 and is continuing.

3.3.3.5 Monitoring Methods for Characterizing Water Pollutants

Identification of Components of Energy-Related Wastes and Effluents

Gulf South Research Institute, New Orleans, Louisiana, is working to identify substances in wastes and effluents from energy-related processes. Information developed from this program will assist researchers who are concerned with control technology, monitoring techniques, and the health and ecological effects of such energy-related pollution.

The proposed work is divided into three phases. Phase A consists of a state-of-the-art summary and work planning which constitutes contacting EPA personnel to determine which energy-related solid waste and aqueous effluents have been analyzed for the purpose of identifying and measuring pollutants and which current contracts and projects will provide further identification . It will also consist of judging the reliability of existing information and the probability of accumulation of adequate data from current contracts and projects using pre-selected criteria. This information will be collated and summarized in a report for EPA. The report will identify the gaps in existing and probable future data on chemical elements and volatile organic compounds in solid wastes and aqueous effluents from coal mines, oil refineries, oil shale processors, coal-fired power plants, coal liquefaction and coal gasification plants.

Phase B consists of selecting sampling sites based on the recommendations from the report prepared in Phase A. The specific aims of Phase C consists of: (1) development and setup of analytical protocol; (2) qualitative and quantitative analyses for elements and organics in aqueous and solid wastes from the selected energy-related processes, and (3) the interpretation and collation of data obtained. Work is being sponsored by EPA ERL-Athens, Georgia. Term of the contract is from September 1976 to September 1979.

3.3.3.6 Development of Techniques for Measurement of Organic Water Pollution

Quality Assurance and Instrumentation in Air and Water Pollution Mining

In cooperation with the EPA and other government agencies, the NBS is developing methodology and standard materials for measuring the environmental effects resulting from increased energy production. The NBS Analytical Chemistry Division is initiating research and development in the areas

of reference materials, instrumentation, and methods required for monitoring air and water quality associated with energy production. The research and development leading to Standard Reference Materials (SRM) instrumentation and methods are urgently needed for the monitoring of air and water quality associated with increased energy development of many different types. Due to the current and future energy problems facing the U.S., it has become imperative for the rapid development of the internal energy capabilities of this country. In order to maintain an acceptable level of environmental pollution, the methods devised for increased utilization of these internal energy sources.(e.g. petroleum, coal, uranium, geothermal) must be adequately evaluated and monitored for effects on air and water pollution. In order to effectively carry out its responsibilities in these areas, the EPA has requested the assistance of the NBS Analytical Chemistry Division for research and development of SRM's.

The overall approach to be taken involves three basic steps. First, in areas of well-defined pollution effects, the emphasis will be on the development and certification of SRM's to enable effective quantitation. Examples of such well defined pollution effects include gases in air pollution (e.g., sulfur dioxide, carbon monoxide) and trace metals in water pollution (e. g., mercury, arsenic, lead). Second, in areas of known effects but imperfect measurement methodology, research and development on analytical methods and instrumentation will be undertaken. Examples of these areas include particulates and trace organics in air and water pollution. Third, in areas of new or increased energy production techniques (i.e., coal gasification and liquefaction, uranium production, etc.), a series of work-shops will be held to help define the current state-of-the-art, and future requirements for analytical reference materials and methodology for air and water pollution measurements. Term of the contract is from 1975 to 1979.

3.3.3.7 Development of Ambient Monitoring Guidelines

Energy-Related Western/Southwestern Regional Air Monitoring

EPA's EMSL-LV is providing integrated and validated air quality monitoring data (baseline and trend) and assessment reports for western areas of the U.S. which will be most seriously affected by energy-related development activities. Emphasis is on fine particulates, nitrogen oxides, sulfur oxides, reactive hydrocarbons, toxic substances, and visibility. The geographical coverage includes the Northern Great Plains, the Four Corners area, oil shale areas of Colorado and Utah, and the Black Mesa areas of Arizona and New Mexico. Term of the contract is from 1975 to 1980.

3.3.4 Health Effects

EPA's Health Effects Research Laboratory, Research Triangle Park, North Carolina (HERL-RTP), and the Environmental Research Laboratory in Gulf Breeze, Florida (ERL-Gulf Breeze), are conducting projects which deal with the effects of air and water pollutants associated with alternative forms of energy development on human health and on aquatic ecosystems.

Laboratory testing is being performed by both in vivo (whole animal) and in vitro (test tube) methods to identify and control hazardous agents. These projects are being conducted by Ball State University, Muncie, Indiana, Northrop Services, Huntsville, Alabama, and by UCLA. In addition, pass-through funds have been given to NIOSH, and DOE's Lawrence Livermore Laboratory (LLL) in Livermore, California, the Los Alamos Scientific Laboratory (LASL) in Los Alamos, New Mexico, and to the Oak Ridge National Laboratory (ORNL), in Oak Ridge, Tennessee.

These projects are in general related to oil shale in that they are multi-technology oriented. The resources associated with them are not exclusively related to oil shale.

3.3.4.1 General Supportive Studies

Establishment of a Chemical Repository for Alternate Energy Source Material for Toxicity Testing

ORNL, under the sponsorship of EPA's HERL-RTP, will provide a repository where materials

from new energy sources can be received, identified, divided into replicate specimens for testing, and forwarded to participating laboratories for testing with sufficient material being held under appropriate methods of storage for future reference. Materials handled include products and combustion effluents from coal gasification and liquefaction, and shale oil extraction. The project duration is from October 1975 to 1978.

3.3.4.2 Pollutant Analysis Studies

Air, Water, and Multi-Route and Health Effects From Pollutants Associated with Energy Development

EPA's HERL-RTP is assessing the health effects of exposures to substances which pollute air and water as a result of energy technologies. Emphasis is being placed on potentially toxic agents resulting from fuel extraction, conversion and combustion. The evaluation of the toxicity of the pollutants and their metabolic products include a spectrum of bioeffect indices.

The present program includes: (1) the assessment of exposure to toxic organic chemicals which are associated with energy processes and which are waterborne. The investigations include screening for potential carcinogens, mutagens, and teratogens in water supplies, as they result from energy sources emphasizing coal and shale oil processing, and (2) toxicologic data obtained for multi-route exposures from metal pollutants resulting from fossil fuel extraction, combustion, and conservation.

Studies also include establishing additional physiological and biochemical indicators to establish a more sensitive dose; data base studies of age sensitivity and influence of dietary composition on adsorption, deposition, and toxicity of the trace elements which pollute the environment from energy-related sources; long-term effects of inhalation exposures to toxic components of fly ash, and biochemical effects of energy-related trace metals on pulmonary macromolecular metabolism. The project duration is from October 1976 to October 1977.

Air, Water, and Multi-Route Exposures and Their Effects: Pollutants Associated with Energy Development

EPA's ERL-Gulf Breeze, is studying the constituents of and compounds derived from petroleum hydrocarbons which may accumulate in portions of the marine food chain consumed by man. The objective of this research is to provide an assessment of the potential for accumulation of specific carcinogens found in fractions of shale oil. Term of this project is from October 1977 to October 1978.

3.3.4.3 In Vivo (Whole Animal) Studies

Effect of Alternate Energy Source Material on Whole Animal Carcinogenesis by Percutaneous Application of Extracts and Fractions to Mice

DOE's ORNL constitutes the lead laboratory for carcinogenesis for the EPA studies of the toxic effects of products and effluents from alternative energy sources. Materials for study are derived through the chemical repository established at ORNL. Materials received are subjected to preliminary toxicity testing and fractionation followed by cancer screening by standard methods, including skin painting and injection. Data from this contract will be used to evaluate data from other methods such as bacterial mutagenesis, neoplastic transformation, intratracheal instillation, etc., to arrive at a comprehensive view of the relative value of various methods in dealing with a practicable evaluation of the carcinogenic potential of crude material. This project is under the sponsorship of EPA's HERL-RTP and IERL-RTP, with funding passed-through to DOE. Project duration is from September 1976 to September 1978.

Morphological Variants in Damaged Sperm

LLL, under sponsorship to DOE is conducting this project. Ionizing radiation as well as various mutagens, carcinogens, and teratogens are known to induce elevated levels of morphologically abnormal sperm in mice. The objectives of this study are: (1) to develop further and apply the detection of morphologically abnormal mouse sperm as a rapid, simple, quantitative assay of

the pathology response of the male gonad to toxic agents; (2) to extend the studies in the mouse to the hamster, and (3) to develop the methodology of automated scoring of abnormally shaped sperm, especially after the exposure of the male to toxic agents. Of special interest are possible effects of the chemical pollutants associated with the recovery, process stream, and emission of non-nuclear sources of energy, especially coal gasification and oil shale extraction in situ.

To accomplish these objectives, groups of test mice have received subacute or chronic exposures by injection, inhalation, or dermal application. The percent of abnormally shaped epididymal sperm will be determined as a function of dosage and time after exposure. These results will be compared to those obtained by more conventional mutagens, carcinogens, and teratogens. Preliminary studies with the hamster and mouse have shown that these two species are qualitatively similar in response. Furthermore, an attempt is being made to distinguish sperm morphology in these species based on suggested differences in fluorescent dye uptake. These results may well lead to automated analyses of sperm morphology. Project duration is from June 1975 to June 1980.

Detection of Early Changes in Lung Cell Cytology by Flow Systems Analysis Techniques

LASL is studying the application of modern automated cytology techniques for assessing damage to humans resulting from exposure to physical and chemical agents associated with oil shale and coal extraction, conversion, and utilization. The approach is to apply unique flow-system cell-analysis and sorting technologies developed at LASL to determine cytological and biochemical indicators of early atypical changes in exposed lung epithelium using the Syrian hamster initially as a model test system.

Current plans are to adapt cell preparation and staining methods developed for flow systems to characterize lung cells from normal and exposed hamsters using the multiparameter cell separator and multiangle light-scatter systems. This includes acquisition of respiratory cells by lavaging the lungs with saline, adapting cytological techniques developed on human gynecological specimens to hamster lung epithelium for obtaining single-cell suspensions, utilization of existing staining techniques for measurement of cellular biochemical properties, and initial characterization of lung cells using flow analysis instrumentation.

LASL has achieved some progress in measuring DNA content, total protein, esterase activity, cell size, nuclear and cytoplasmic diameters, and multiangle light-scatter properties of exfoliated hamster lung cell samples composed of macrophages, leukocytes, epithelial, and columnar cells. As this new technology is adapted further to analyze lung cells from hamsters and subsequent characterization studies are completed, measurement of changes in physical and biochemical cell properties as a function of exposure to toxic agents associated with synthetic fuels energy production will be performed, with eventual examination of sputum samples from occupationally exposed humans. This project is being sponsored by DOE with EPA pass-through funds. Term of this project is from 1976 and is continuing.

Mortality, Morbidity, and Industrial Hygiene Study of Oil Shale Workers

NIOSH is studying 320 men who have worked in pilot oil shale operations. The men are divided into three groups consisting of workers from: (1) the U.S. Bureau of Mines; (2) the Joint Venture of the Colorado School of Mines Research Institute, Anvil Points, Colorado, and (3) the Union Oil Retort facility in Grand Valley, Colorado.

A retrospective mortality study of approximately 60 men will be done in-house while a cross-sectional morbidity examination to evaluate several morbidity aspects that may be associated with oil shale occupations will be done by contract. Mortality due to 21 specific causes of death will be determined after an extensive follow-up effort and the death certificates of those who have died will be examined. The various causes of death will be examined to determine if an excessive number of deaths were due to a particular cause. Numerous indices of health regarding the living men will be assessed through physical examinations and health questionnaires. NIOSH has contacted various people knowledgeable in oil shale technology, as well

as others who are or have been involved in health studies related to oil shale mining and retorting.

Recently, an additional contract was signed by NIOSH with Utah Biomedical Testing Laboratory, Salt Lake City, to conduct testing on cancer of the bladder and respiratory system. NIOSH's efforts are supported by EPA pass-through funds. Term of the contract is from November 1976 to November 1978.

Determination of the Influence of Mineral Cofactors in Conjunction with Carcinogens from Energy-Related Materials

Northrop Services, Huntsville, Alabama, is under contract to the EPA's HERL-RTP to determine the influence of environmental materials such as fibrous amphiboles, fine particles, etc., as cofactors with carcinogenic influences from alternative energy sources such as coal gasification and liquefaction, and shale oil products and effluents. Intratracheal instillation and intrapleural innoculation would be used and the end points would be formation of cancer in the lung or pleura or development of precancerous lesions compared to appropriate controls. The duration of this project is from December 1975 to August 1978.

In Vivo Screening for Gene Mutation in Mouse Germ and Somatic Cells

DOE's ORNL is conducting this study with EPA pass-through funds. In screening for mutagenic agents it is important to include mammalian tests for gene mutations. In this project, identification of mutagens associated with coal and oil shale technologies that can induce gene mutations and small deficiencies will be accomplished by scoring for: (1) transmitted specific-locus mutations induced in germ cells, and (2) somatic mutations in coat color genes.

The specific-locus method developed has been used extensively in radiation work and has already proved its usefulness in chemical mutagenesis studies. It is the only established, reliable, and definitive test for transmitted gene mutations and small deficiencies currently available in mammals. To make the method economically efficient for screening purposes, it will be used to test whether there is anything mutagenic in a whole mixture of compounds, for example, in an effluent. One mixture from a coal conversion process that has just become available after studies with non-mammalian systems is now being used in preliminary toxicity tests. An in vivo somatic-mutation method, developed in an earlier X-ray experiment, has now been explored for its usefulness in the prescreening for germinal point mutations induced by chemicals. In an array of seven compounds tested, parallelism with spermatogonial specific-locus mutation rates was found, indicating that the in vivo somatic-mutation test may detect point mutations in addition to other types of genetic changes that lead to expression of the recessive. The method is now being used to test fractions from coal conversion processes. Term of this contract is from 1976 and is continuing.

3.3.4.4 In Vitro Studies

Determination of the Effects of Material from Alternate Energy Sources on Upper Respiratory Tract Clearance Mechanisms

Ball State University, Muncie, Indiana, under sponsorship to EPA's HERL-RTP, is screening a variety of substances for their toxic effect on mucociliary activity using an in vitro model system. Since cilia play a significant role in pulmonary clearance, proper functioning is essential for defense against various environmental insults. However, ozone, nitrogen dioxide, nickel, and cadmium have an adverse effect on this system. Therefore, it becomes increasingly important to determine if alternative energy sources such as shale oil and coal gasification and liquefaction, or particulate effluents from power stations, stationary engines or mobile sources produce pollutants toxic to the mucociliary escalator.

Consequently, isolated hamster tracheal rings are exposed to pollutants in vitro. Parameters measured are the: (1) effect on ciliary beat frequency; (2) effect on the energy source (ATP) of beating; (3) effect on ciliary and tracheal morphology, and (4) recovery of the tracheal rings after exposure. In all cases, parameters are tested for dose-response effects. Project duration is from October 1975 to May 1979.

Quantitative Mutagenesis Testing in Mammalian Cellular Systems

LLL is to develop and apply quantitative and multiple-marker assays utilizing cultured mammalian cells to evaluate the potential mutagenic effects of agents derived from energy technologies. Additionally, LLL will use these existing and newly-developed biological screening systems to identify mutagenic agents associated with coal and oil shale extraction, conversion, or utilization.

This program proposes the use of multiple drug-resistance markers for forward mutation in cultured Chinese hamster ovary (CHO) cells, as well as in vitro and host-mediated in vivo/in vitro procedures in the Syrian hamster embryo (SHE) system. The markers being developed measure the frequency of forward mutation at the recessive azaadenine-resistant marker, the X-linked azaguanine-resistant phenotype, and the dominant ouabain-resistant locus. Established procaryote and lower eucaryote systems will be used for comparison and reference; the most satisfactory markers in all systems will then be combined into a standard protocol in which each of the gene loci can be measured for mutation following exposure to a particular test agent or combination.

To date, both CHO and SHE systems have been tested with the standard mutagen EMS, and experiments using specific hydrocarbons relevant to energy technology are now underway. This project is being sponsored by DOE under pass-through funds from EPA. Project duration is from June 1975 to June 1980.

Development of Cytochemical Markers for Cell Transformation and Carcinogenesis

LLL is developing rapid, sensitive, and economical systems for the in vitro and cytological assay for carcinogenic effects of substances involved in the extraction, conversion, and utilization of non-nuclear energy sources, with particular consideration of in situ coal gasification, shale oil utilization, coal burning power plants, and geothermal power plants. The approach is based on the development of cytochemical markers for cell transformation, and on the ability to quantify such markers by microfluorometry and by flow system analysis and sorting.

There are two phases to this work: (1) the development of appropriate test systems whose response is defined by well characterized and representative carcinogenic agents, and (2) the application of such systems to substances released by energy technologies, and including testing with whole and fractionated samples of effluents. This project is under the sponsorship of DOE with pass-through funds from EPA. Project duration is from June 1975 to June 1980.

Somatic Cell Genetics

LASL sponsors a genetics program which is isolating temperature sensitive mutants (variants) of the mammalian cell for use in studying the genetics of cell life-cycle traverse. In addition to these mutants, several auxotrophic clones have been isolated and a mutation system has been developed for use in assessing the mutagenicity of suspected carcinogens derived primarily from coal gasification and oil shale extraction processes. The Ames Salmonella/microsome test system will serve as an ancilliary test for mutagenicity. The mammalian cell forward and reverse mutation system and the Ames bacterial test system currently are functional in this laboratory. Temperature-sensitive life-cycle traverse mutants are being analyzed to determine in what phase of the life-cycle the ts phenotype is expressed using the LASL flow microfluorometer. This project is sponsored by DOE under pass-through funds from EPA. This is a two-year program ending in 1977.

Analysis of the Effects of Energy-Related Toxic Materials to Karyotype Stability in Mammalian Cells

LASL is developing systems for the rapid detection of karyotypic changes in mammalian cells as a result of exposure to energy-related environmental pollutants and to screen selected subjects utilizing these systems. Flow microfluorometry (FMF) of isolated, fluorescently stained chromosomes will be used to identify chromosome aberrations, and FMF of stained intact cells will be used to detect mitotic nondisjunction. Cadmium will be

used as the clastogenic agent in the development of a test system. It has been demonstrated that chromosome analysis can be accomplished by flow systems in mammalian cells with relatively simple karyotypes. Cadmium at low concentrations is a potent clastogen. It induces primarily chromatidtype aberrations.

LASL has also demonstrated that tolerance to the damaging effects of cadmium can be induced in fibroblast cells in culture by long-term exposure of the cells to sublethal concentrations of cadmium. Repeats of these experiments are planned on human fibroblast and lymphocyte cells in vitro and to extend these studies to other toxic agents associated with alternative energy technologies. This project is being sponsored by DOE with EPA pass-through funds. Term of the contract is from 1976 and is continuing.

Effects of Agents Associated with Coal and Oil Shale Extraction, Conversion or Utilization on Cell-Cycle Kinetics and on Chromatin/Chromosome Structure

LASL is providing a means for detecting and monitoring damage to humans as a result of exposure to various toxic chemical and physical agents. To obtain an idea of the parameters to be monitored in humans, it is first necessary to establish the effects of agents on cells in simpler model systems.

Earlier experience with drugs which act as carcinogens and teratogens has convinced researchers that changes in population cell-cycle distribution and alterations in chromatin structure may provide useful early indicators of sublethal damage to cells exposed to hazardous agents. Examination will be made of alterations in these parameters following exposure to specific energy-related toxic substances in currently available tissue-culture systems which show promise as a predictive indicator of response of humans. A technique has been developed that allows preparation of both cycling and noncycling cell populations in tissue-culture, mimicking these classes of somatic cells in humans. By combining autoradiography, cell number enumeration, and flow micro-fluorometry, it will be possible to obtain highly detailed information regarding the cellular kinetics response of both arrested and cycling populations to treatment with toxic agents.

Results obtained to date suggest that DNA-interactive agents elicit different types of kinetics responses in treated cells, indicating a degree of specificity of interaction between various alkylating and intercalating agents and the genome. This project is sponsored by DOE with EPA pass-through funds. Term of the contract is from 1976 and is continuing.

Development of Permanent Epithelial Cell Lines

DOE's ORNL is conducting this study with EPA pass-through funds. Objectives are: (1) to develop the means by which chemicals associated with non-nuclear energy generation, especially agents arising from coal and oil shale extraction, can be screened for potential carcinogenic activity reliably, quickly, and cheaply relative to current animal exposure techniques, and (2) to utilize appropriate cultured cells developed in (1) for the study of hydrocarbon carcinogen metabolism to active forms and the mechanism of chemical carcinogenesis.

A research group with two discrete but closely related approaches to these problems is being developed. The approaches are: (1) cell biology - the major focus here will be the development of permanent cell lines of epithelial origin (human, when possible and appropriate) which possess the enzymetic equipment for carcinogen activation and which are transformable with high frequency, and (2) biochemistry - principal focus will be the study of metabolism of polycyclic hydrocarbons in various cell lines developed in approach (1), to establish with certainty the "ultimate" carcinogenic metabolite, using primarily high pressure liquid chromatography techniques. Term of the contract is from 1976 and is continuing.

Development of An In Vitro Assay for Co-Carcinogenesis of Coal/Oil Shale Derivatives

The UCLA School of Medicine is developing an in vitro assay capable of detecting the co-carcinogenic potential (with X-rays) of materials produced during coal and oil shale processing.

Initially it was proposed to utilize mouse tissue cultured cells and an already established transformation assay. Initial experiments indicated that rodent cells may process lesions induced by alkylating agents different from human cells and that their use as screening materials might be misleading. This was shown by demonstrating that a variety of DNA damaging agents yielded significantly different effects on various cell lines when measured by a variety of techniques.

It was hypothesized that a ventral difference between the lines (rodent versus human) may be the "activation of on-cogenesis" related to the strand breakage induced, and because rodent lines carry transforming virus materials of a complete or incomplete nature, which is lacking in most human target cells. This is being evaluated through cell hybridization analysis using hybrids made by sendaivirus fusion of cells lacking either: (1) different DNA repair enzymes, or (2) (potential) RNA viruses. This project is sponsored by DOE with EPA pass-through funds. This contract began in 1976 and is continuing

3.4 INTEGRATED ASSESSMENT

Two projects are currently active under the integrated assessment program. The USDA, working with EPA pass-through funds, is studying the socio-economic consequences of coal and oil shale development and, the University of Oklahoma, Norman, Oklahoma, is performing a technology assessment of energy development in the western U.S.

Integrated Assessment: Socio-Economic Consequences of Coal and Oil Shale Development

USDA's Economic Research Service, Washington, D.C., is working to describe current resource use in coal and oil shale extraction and to assess agricultural economic implications, resource competition, and use resulting from coal and oil shale development. This work will also estimate the impact of energy development in the Northern Great Plains on employment, income, and population of rural communities and of local government finances and services, including revenue potential. Interrelationships of local government expenditures to employment, population, income, age structure, and other socio-economic variables will be analyzed. The work will evaluate costs of mined land reclamation and uses for land after mining. Interregional economic implications and tradeoffs for agricultural and rural areas resulting from coal development will also be evaluated. Included are effects of increased water demand for coal development on agricultural industries, environmental quality, and rural resource use. This project is funded by EPA pass-through funds to USDA. The duration of this project is from March 1976 to June 1979.

Technology Assessment of Western Energy Resource Development

The University of Oklahoma is under contract to determine the effects of development of six energy resources on the western U.S. The energy resources under study are: coal, geothermal, natural gas, oil, uranium, and oil shale. The study comprises an eight-state area including: Arizona, Colorado, Montana, New Mexico, North and South Dakota, Utah, and Wyoming. The results of the assessment will be used by EPA in developing pollution control policies and their associated implementation strategies applicable to western energy resource development.

Recently, the University of Oklahoma, in conjunction with Radian Corporation of Austin, Texas, released a four-volume report titled, "Energy from the West: A Progress Report of a Technology Assessment of Western Energy Resource Development," EPA-600-/7-77-072. It is a progress report of a three-year technology assessment of the development of the six energy resources. More reports are expected to be released. The contract began in July 1975 and is scheduled for completion in late 1978.

Table 1
CURRENT PROGRAM STATUS SUMMARY

TITLE	SPONSOR	PERFORMING ORGANIZATION	DURATION	CONTACT
EXTRACTION AND HANDLING				
Technologies for Controlling Adverse Effects of Mining on Forest, Range and Related Freshwater Ecosystems	EPA pass-through to USDA	USDA	4 years	R.Z. Callhan (703)-235-1071
Water Quality Hydrology Affected by Oil Shale Development	IERL-CIN	Colorado State University	5 years	Eugene Harris (513)-684-4417
Fugitive Dust from Oil Shale Extraction	IERL-CIN	TRW	8 months	Edward Bates (513)-684-4417
Vegetative Stabilization of (TOSCO and USBM) Spent Oil Shale	IERL-CIN	Colorado State University	6 years	Eugene Harris (513)-684-4417
Vegetative Stabilization of Paraho Spent Oil Shale	IERL-CIN	Colorado State University	3 years	Eugene Harris (513)-684-4417
PROCESSING				
Environmental Impact of Oil Shale Development	IERL-CIN	TRW/DRI	2 years	Thomas Powers (513)-684-4402
Sampling and Analysis of the Paraho Surface Retort	IERL-CIN	TRW/DRI	3 years	Thomas Powers (513)-684-4402
Program Support in Environmental Assessment and Control Technology Development for Advanced Fossil Fuels	OEMI	Cameron Engineers	2 years	William N. McCarthy, Jr. (202)-755-2737
ENERGY-RELATED PROCESSES AND EFFECTS-Ecological Effects				
Toxic Effects on the Aquatic Biota from Coal and Oil Shale Development	ERL-Duluth	ERL-Duluth	3 years	Leonard Mueller (218)-727-6692
ENERGY-RELATED PROCESSES AND EFFECTS-Environmental Transport Studies				
The Mineralogy of Overburden as Related to Groundwater Chemical Changes in Strip Mining of Coal, In Situ Coal Gasification, and Oil Shale Development	Kerr-ERL	Kerr-ERL	4 years	Robert Newport (405)-332-8800
ENERGY-RELATED PROCESSES AND EFFECTS-Measurement and Monitoring				
Oil Shale Area Meteorological Data Analysis	Region VIII	CDM Limnetics	16 months	Terry Thoem (303)-837-5914
Air Quality and Surface Wind Monitoring in Colorado	Region VIII	Colorado Dept. of Health	2 years	Terry Thoem (303)-837-5914
Upper Air Meteorological Data Collection	Region VIII	Aeromet, Inc.	2 years	Terry Thoem (303)-837-5914

Table 1
CURRENT PROGRAM STATUS SUMMARY (Cont.)

TITLE	SPONSOR	PERFORMING ORGANIZATION	DURATION	CONTACT
Monitoring the Impact of Western Coal Strip Mining and Oil Shale Extraction on Groundwater Quality	EMSL-LV	General Electric	5 years	Leslie McMillion (702)-736-2969
Energy-Related Water Monitoring Data Integration	EMSL-LV	EMSL-LV	5 years	Victor Lambou (702)-736-2969
Water Quality and Geochemistry of Shallow Aquifers of Piceance Creek, Colorado	EPA pass-through to USGS	USGS	5 years	F.A. Kilpatrick (703)-860-6846
Water Quality Monitoring on White River, Parachute Creek and Logan Wash in Oil Shale Areas in Western Colorado	EPA pass-through to USGS	USGS	5 years	F.A. Kilpatrick (703)-860-6846
Collection of Geochemical Data in the Piceance Creek Structural Basin of Colorado	EPA pass-through to USGS	USGS	2 years	F.A. Kilpatrick (703)-860-6846
Potentiometric Surface of Shallow Aquifers in Piceance Creek Structural Basin	EPA pass-through to USGS	USGS	3 years	Jack Weeks (303)-234-5092
Instrumentation and Methods for Characterizing Aqueous Effluents from Oil Shale	EPA pass-through to DOE	Oak Ridge National Laboratory	1976-continuing	Bruce Clark (202)-755-2673
Identification of Components of Energy-Related Wastes and Effluents	ERL-Athens	Gulf South Research Institute	3 years	Ann Alford (404)-546-3186
Quality Assurance and Instrumentation in Air and Water Pollution Mining	EPA pass-through to NBS	NBS	4 years	Jerry McNesby (301)-921-2446
Energy-Related Western/Southwestern Regional Air Monitoring	EMSL-LV	EMSL-LV	5 years	David McNelis (702)-736-2969
ENERGY-RELATED PROCESSES AND EFFECTS-Health Effects				
Establishment of a Chemical Repository for Alternate Energy Source Material for Toxicity Testing	EPA pass-through to DOE	Oak Ridge National Laboratory	3 years	Dr. David Coffin (919)-549-8411
Air, Water, and Multi-Route and Health Effects from Pollutants Associated with Energy Development	HERL-RTP	HERL-RTP	12 months	J.F. Stara (513)-684-7401
Air, Water, and Multi-Route Exposures and Their Effects: Pollutants Associated with Energy Development	ERL-Gulf Breeze	ERL-Gulf Breeze	12 months	Dr. Norman Richards (904)-932-5311
Effect of Alternate Energy Source Material on Whole Animal Carcinogenesis by Percutaneous Application of Extracts and Fractions to Mice	EPA pass-through to DOE	Oak Ridge National Laboratory	2 years	Dr. David Coffin (919)-549-8411
Morphological Variants in Damaged Sperm	EPA pass-through to DOE	Lawrence Livermore Laboratory	5 years	Dr. George Stapleton (301)-353-5468

Table 1
CURRENT PROGRAM STATUS SUMMARY (Cont.)

TITLE	SPONSOR	PERFORMING ORGANIZATION	DURATION	CONTACT
Detection of Early Changes in Lung Cell Cytology by Flow Systems Analysis Techniques	EPA pass-through to DOE	Los Alamos Scientific Laboratory	1976-continuing	Dr. George Duda (301)-353-5468
Mortality, Morbidity, and Industrial Hygiene Study of Oil Shale Workers	NIOSH	NIOSH	2 years	Dr. John Finklea (301)-443-1530
Determination of the Influence of Mineral Cofactors in Conjunction with Carcinogens from Energy-Related Materials	HERL-RTP	Northrop Services	32 months	Dr. David Coffin (919)-549-8411
In Vivo Screening for Gene Mutation in Mouse Germ and Somatic Cells	EPA pass-through to DOE	Oak Ridge National Laboratory	1976-continuing	Dr. George Stapleton (301)-353-5468
Determination of the Effects of Material from Alternate Energy Sources on Upper Respiratory Tract Clearance Mechanisms	HERL-RTP	Ball State University	42 months	Dr. Donald Gardner (919)549-8411
Quantitative Mutagenesis Testing in Mammalian Cellular Systems	EPA pass-through to DOE	Lawrence Livermore Laboratory	5 years	Dr. George Stapleton (301)-353-5468
Development of Cytochemical Markers for Cell Transformation and Carcinogenesis	EPA pass-through DOE	Lawrence Livermore Laboratory	5 years	Dr. George Duda (301)-353-5037
Somatic Cell Genetics	EPA pass-through to DOE	Los Alamos Scientific Laboratory	2 years	Dr. George Duda (301)-353-5037
Analysis of the Effects of Energy-Related Materials to Karotype Stability in Mammalian Cells	EPA pass-through to DOE	Los Alamos Scientific Laboratory	1976-continuing	Dr. George Duda (301)-353-5037
Effects of Agents Associated with Coal and Oil Shale Extraction, Conversion, or Utilization on Cell Cycle Kinetics and on Chromatin/Chromosome Structure	EPA pass-through to DOE	Los Alamos Scientific Laboratory	1976-continuing	Dr. George Stapleton (301)-353-5468
Development of Permanent Epithelial Cell Lines	EPA pass-through to DOE	Oak Ridge National Laboratory	1976-continuing	Dr. George Duda (301)-353-5037
Development of An In Vitro Assay for Co-carcinogenesis of Coal/Oil Shale Derivatives	EPA pass-through to DOE	UCLA School of Medicine	1976-continuing	Dr. George Stapleton (301)-353-5468
INTEGRATED ASSESSMENT				
Integrated Assessment: Socio-Economic Consequences of Coal and Oil Shale Development	EPA pass-through to USDA	USDA	39 months	John Schaub (202)-447-8104
Technology Assessment of Western Energy Resource Development	OEMI	University of Oklahoma	3 years	Steve Plotkin (202)-755-0647

APPENDICES

Appendix A

WORLD RESOURCES AND DEVELOPMENT HISTORY

Oil shale, by one name or another, occurs on all continents and is known to exist in nearly three dozen countries. Few of the known occurrences and practically none of the large occurrences have ever been completely explored. The principal exception is the Green River Formation in Colorado, Utah, and Wyoming. Total world resources are thus unknown, but it must be measured in hundreds of trillions of barrels. Asia is believed to contain the most oil shale, with Africa running a close second. Still, the Green River deposit is the largest single known concentration of hydrocarbons in the world.

USA

The Ute Indians and their predecessors probably used oil shale as a fuel long before white man found his way to the Piceance Creek basin. Later on, the Mormons distilled oil from shale near Juab, Utah, where the ruins of an old retort still exist.

It wasn't until World War I that serious interest was given to utilizing Green River oil shale. More than 50 oil shale companies had operated in the eastern U.S. prior to when Colonel Drake's Pennsylvania oil well was drilled in 1859. These early operations were crude, and no attempt had ever been made to apply the technology to the deposits of western shales discovered in the 1880's.

Western oil shale activity began in the 1890's in Nevada. A businessman named Robert Catlin acquired oil shale properties near Elko between 1890 and 1915. He visited Broxburn, Scotland, in 1901 to study the Scottish operations and eventually began R&D with Elko deposits in 1914. A 100-foot shaft was sunk on his property in 1915 and the following year he erected a 20 ton-per-day retort which proved to be unsatisfactory and was later dismantled. In 1917, he incorporated Catlin Shale Products Company.

In 1918, the company began constructing eight 100 ton-per-day retorts which differed in design from the 1915 models. The retorts were in operation in May 1919, and by July, the new plant had produced 15,000 gallons of shale oil. The refrigerator plant, wax press, stills, and agitator were added to the plant late in 1919 and in early 1920. Sometime later, the Catlin Company's retorts were shut down. A third retort, 40 feet high and 12½ feet in diameter, was constructed and put in operation in December 1921. This retort was operated intermittently until October 18, 1924. In 1924, the shale oil products were offered for sale for the purpose of testing the market. The products apparently could not be marketed in competition with petroleum products. On December 23, 1930, the company was dissolved. Its operation admittedly was experimental.

The Oil Shale Mining Company was apparently the first group to undertake R&D efforts with Green River Formation oil shale. It was incorporated in Colorado on October 2, 1916, as a public stock company with a capitalization of $100,000. It acquired six mining claims about 15 miles west of DeBeque, Colorado. An externally heated, six to eight ton-per-day batchtype Henderson retort, 18 feet high and 12 to 15 inches in diameter, and a tramway were constructed. By the end of 1918 or the early part of 1919, the company had six of these retorts, only one of which was assembled and operated on an experimental basis. By 1920, the company experimented with a continuous type of retort, invented by its superintendent, A.V. Young, which was subsequently abandoned.

The company produced a few barrels of oil in 1920 and 30 barrels in 1921. Ore for the retorts was obtained from small pits on the claims from 1917 to 1921. By 1926, the company lost its properties through attachments.

The stories of the Catlin Shale works and the Oil Shale Mining Company are illustrative of

dozens of similar operations that existed during the decade following World War I. Most operations were experimental in nature and none ever produced more than a few thousand barrels.

By 1925, more than two dozen experimental plants were operating throughout the country, using Devonian as well as Green River shales. But interest in oil shale was not limited to the entrepreneur. Cities Service, Standard Oil of California, and Texaco began acquiring oil shale properties and investigating shale oil production in 1918. Union Oil Company of California followed suit in 1920. Standard of California conducted laboratory retorting experiments in 1920 and from 1925 to 1928.

The U.S. Bureau of Mines built and operated the N-T-U retort from 1925 to 1929, using Colorado oil shale.

During the mid-1920's, Union conducted studies of existing oil shale processes, made analyses of oil shale samples and undertook an oil shale research program. Starting in 1944, it built and operated an experimental retort with a capacity of two tons-per-day. In 1948, it completed a 50 ton-per-day retort which was dismantled in 1954. Construction of a 1,000 ton-per-day demonstration plant was started in 1955 on Parachute Creek north of Grand Valley, Colorado. The plant was completed in 1957 and operated until mid-1958.

Mobil Oil Corporation began a research program to evaluate the potential of oil shale in 1943. A pilot plant was built at Paulsboro, New Jersey, and an experimental program was conducted between 1943 and 1945. In 1965 through 1967, Mobil was operator of a six-company group that leased the Anvil Points demonstration facility near Rifle, Colorado, and further developed gas combustion retorting technology.

Texaco's R&D activities also date to the 1940's. From 1945 to 1947, Texaco prepared a shale oil refining study for the Navy at its own expense. Beginning in 1957 after experimentation with other methods of extracting oil from shale, Texaco built and operated a pilot plant to develop its own hydrotorting process.

Congress passed the Synthetic Liquid Fuels Act in 1944 because of the tremendous demands for liquid fuels imposed by World War II. This led to construction and operation of the Anvil Points Oil Shale Demonstration Facility of the U.S. Bureau of Mines. Six, 25, and 150 ton-per-day pilot plants were operated between 1950 and 1955.

The Paraho Oil Shale Project was a three-year program aimed at demonstrating the feasibility of the Paraho process. The program was administered by Development Engineering, Inc., under the leadership of Harry Pforzheimer of SOHIO. The program was conducted at the Anvil Points Oil Shale Facilities near Rifle, Colorado. These facilities are leased from DOE. The project was launched in 1973 with funds from seventeen participating companies. At the present time, the Paraho facility at Anvil Points is involved in the production of 100,000 barrels of shale oil under contract to the U.S. Navy. The Navy intends to have this shale oil refined into military specification products by an independent contractor.

In 1968, the Department of Interior (DOI) instituted the Oil Shale Test Leasing Program. An oil shale leasing study was initiated by DOI in October 1969 which subsequently led to the Final Environmental Impact Statement released in August 1973.

Commencing with competitive bid sales in January 1974, the DOI offered the lease of the six selected tracts in Colorado, Utah, and Wyoming, and during the following six months leased four of these tracts, two each in Colorado (Tracts C-a and C-b) and Utah (Tracts U-a and U-b). Neither of the two Wyoming tracts received acceptable bids.

The C-b Shale Oil Project lease was awarded in April 1974 to a group composed of Ashland Oil, Inc., the Atlantic Richfield Company, Shell Oil, Inc., and The Oil Shale Corporation (TOSCO). Later, three of the companies withdrew from the project, leaving Ashland Oil. On November 3, 1976, Occidental Petroleum Corporation (OXY) entered into an agreement with Ashland Oil whereby OXY gained a 50 percent interest in Tract C-b in exchange for their technology concerning the modified in situ process.

Occidental and Ashland plan to develop Tract C-b in a progressive fashion which will allow early evaluation of the modified in situ technology on the new site prior to construction of a full scale commercial facility. Current plans call for constructing a small retort test area which can begin operations while development of the commercial mine and retorts is underway. It is expected that the first retort will be ready for processing by November 1980. When the commercial facility reaches full production by 1983, approximately 40 retorts will be in various stages of "burning" at the same time. This will produce a total of 57,000 barrels of shale oil daily. Utilizing OXY's modified in situ technology will result in the production of approximately 1.2 billion barrels of the 3.0 billion barrels of shale oil in place on the tract. If it is determined that surface retorts can be used to process the mined out shale, total recovery will be about 1.65 billion barrels of oil. Occidental and Ashland estimate that the required capital cost of the Tract C-b oil shale facility will be $440 million. In turn, development of the tract will result in 1,600 permanent jobs for the duration of the 56-year project.

The White River Shale Project is a joint development of Tracts U-a and U-b in northeastern Utah. The lease on Tract U-a was awarded to Phillips Petroleum Company and Sunoco Energy Development Company (then Sun Oil Company) in May 1974. Sohio Petroleum Company then joined Sunoco and Phillips to create the White River Shale Oil Corporation which was awarded a lease on Tract U-b in June 1974.

White River plans to follow a modular development approach in commercializing oil shale operations on Tracts U-a and U-b. The first major activity on the tracts will be to establish a room and pillar mine with its attendant access shafts. This Phase I developmental mine will better define the shale conditions existing on the tract which will have an effect on future large scale mining and processing operations. During this initial mining operation, about 30,000 tons of shale will be mined for crushing and retorting evaluations. During Phase II this exploratory mine will be enlarged to the point where it can produce about 10,000 tons of oil shale per day. This oil shale will subsequently be crushed and fed to a single commercial sized vertical retort. Successful initiation and operation of the single retort installation will be followed by engineering and construction of a commercial plant. For the commercial plant producing 100,000 barrels of shale oil per day the mining operations will produce about 160,000 tons per day of raw shale.

White River estimates that the cost for commercial development on Tracts U-a and U-b will be approximately $1.6 billion. Long-term commercial development will result in the creation of 2,050 permanent jobs. Because of the high costs involved, and because of the risks and uncertainty surrounding such a project, White River feels that the ultimate development of Tracts U-a and U-b may require government support. White River has recently proposed a $246 million modular demonstration plant to be funded via DOE. The demonstration plant would include both modified in situ and surface retorts. Future development on Tracts U-a and U-b, however, is clouded by a legal question concerning ownership of the leased lands. This issue is currently being considered by the courts, and no development on the tracts is likely until these issues are resolved.

OTHER COUNTRIES

Oil shale industries have existed at one time or another in 13 other countries. The first recorded production of shale oil was in Austria in 1350. A 14th century British patent refers to deriving "a kind of oyle from a stone." The first recorded installation of oil shale retorts to produce oil as fuel was in France in 1838.

Two recurrent situations are noted in the history of oil shale development since 1838. First, it has only occurred under unusual, localized conditions, primarily where no viable sources of coal or crude oil were available or where they were inadequate. Only two significant industries still exist today -- in Manchuria and Estonia. They both meet this condition. When supplies of crude oil were adequate, oil shale has never been able to compete economically, unless subsidized.

The second situation is that, until very recently, oil shale industries were at their best just before, during, and immediately following World War II.

Australia

Oil shale occurrences were first noted in Australia in 1802 and numerous small operations existed from 1865 to 1945; however, there has been only one significant Australian operation. That was the Glen Davis Plant in New South Wales. It was operated between 1938 and 1955 by a government subsidized company that was created for that purpose in 1937. Its oil shale came from the Newnes Capertee deposit near Glen Davis. The plant featured the use of about 100 vertical kiln retorts patterned after the Scottish Pumpherstone-Fell type. Each retort handled 7 or 8 tons of 70 gallons-per-ton shale per day and recovered about 90 percent of the assay value of the feed shale. The total theoretical capacity was thus about 11,000 barrels daily, but the complex apparently only produced a level of about 1,500 barrels per day. Operations proved to be uneconomical after World War II and the facilities were abandoned.

During the war, however, many "backyard" oil shale operations existed, one of these was operated by Lithgo Oil Party Ltd. at Marangaroo, New South Wales, and produced over 2 million gallons of oil at a time when every drop of liquid fuel counted.

Today, there is no shale oil production anywhere in Australia. An exploration program to prove up new reserves was conducted during the late 1950's but only questionable prospects were identified. Two large exploration programs are underway now and tentatively plans are being made for potential renewal of an Australian oil shale industry.

Austria

Production of shale oil was first recorded in Tyrol in 1350 A.D. but there are indications that this began even much earlier. Around 1600, shale oil or "rock oil" as it was called was discovered to have medical value and many primitive works produced oil for trading and local consumption. Shale oil production attained some economic significance in 1839 when an asphalt factory began operation. Between 1840 and 1882, oil shale was employed mostly for the extraction of asphalt mastic, naphtha, and asphalt tar. By 1900 the therapeutic value of shale oil was again recognized and since then has been produced solely for medical purposes in the field of dermatology. From 1937 to 1966, the annual use was about 600 tons. Some use of shale oil probably continues today, but the relatively small reserves and complicated mining situation leave significant oil shale use in Austria in doubt.

Brazil

Reserves of medium-quality Irati shale oil in Brazil are known to be adequate for an extremely large industry, but large scale commercial exploitation was not seriously considered until after World War II. Nevertheless, it is known that illuminating gas was produced from oil shale in the Pariaba Valley as early as 1882. Small scale operations existed off and on thereafter until 1946.

In 1950, the Brazilian government launched a major research program to develop a practical technology for utilizing Irati shale. Bench scale and pilot plant studies during the 1950's and 1960's resulted in development of the Petrosix process. In addition to oil, the Petrosix process yields LPG, high-BTU fuel gas, and elemental sulfur and all are products of importance in Brazil.

Meanwhile, Brazil's oil shale was explored, in reconnaissance fashion, over most of the southern part of the country. Geologists ultimately selected a site near Sao Mateus do Sul in the southern part of the State of Parana for a concentrated exploration effort. Coreholes were drilled on a 100 meter grid pattern and reserves of some 700 million barrels were delineated and plans were made in the mid-1960's to establish a demonstration Petrosix plant at this site.

Operation of the 2,200 ton-per-day demonstration plant began in 1973. The Petrosix retort installed at the plant was designed by Cameron Engineers.

The retort is the focal point of an impressive complex that includes facilities for crushing, screening, fines briquetting, oil separation, LPG and sulfur recovery from retort off-gas, and power production. A new town was established at nearby Curitiba, complete with attractive residences and schools plus all the necessary amenities such as a water and sewer system and roads paved with crushed oil shale.

A nearby surface mine provides shale to the plant, which is located near the oil shale outcrop. Oil shale is recovered from two beds near the surface but separated by a bed of barren limestone.

By 1976, the Brazilians had become experts at operating the plant and began serious studies of starting a large-scale commercial industry. The 2,200 ton-per-day retort is some 18 feet in diameter and it may be used as the first in a battery of commercial-scale modules that would be built at the existing complex. But it is likely that Petrobras may seriously consider going to a retort twice the diameter and four times the throughput. In any event, it would be no surprise to hear Brazil announce firm plans for a large-scale industry before 1980.

Burma

The Burmese oil shale deposit is an extension of that in Thailand. Reserves are not large but quality appears to be good. There has never been any commercial production.

Canada

Oil shales from the maritime provinces were distilled to produce waxes and illuminating oils in the early 1800's, but no significant industry ever existed. Studies during the last decade have failed to provide an economical means of using Canadian shales from either Saskatchewan or the maritime provinces. Reserves are substantial but quality is marginal. The best use may prove to be for production or direct burning for power generation.

France

The world's first recorded production of shale was in France in 1838. France's shale oil industry apparently flourished until the discovery of conventional liquid petroleum. After that, the French government from time to time provided various kinds of financial support such as duties on imports or direct subsidies. The French industry apparently used the Scottish Pumpherstone retort almost exclusively after 1860 and until the 1940's when French-designed retorts replaced the smaller Pumpherstone. Production apparently reached an all-time high of 500,000 tons in 1947 but declined steadily thereafter. Still, three plants were in operation as late as 1950, each receiving indirect government subsidies of one kind or another. The industry ceased in the 1960's.

Germany

The first recorded utilization of oil shale in Germany was in 1916, but little is known of the early industry - - it probably existed on only a pilot or experimental scale. By 1937, only one small plant was in operation. It consisted of a series of small vertical retorts held in masonry and externally heated with hot gases. Production was not large and the plant did not play an important part in subsequent developments in Germany. In 1940, oil shale operations began at a former portland cement plant in Dotternhausen.

Germany, of course, has large deposits of brown coal and lignite in addition to oil shale. During the 1930's the Hitler regime focused efforts on producing liquid fuels from coal and lignite. This resulted in improvements to the Bergius and Fischer-Tropsch processes and the installation of full-scale industrial plants. Early in World War II these synthetic fuels plants using coal seemed adequate to meet Germany's wartime needs for liquid fuels, but the situation quickly changed after the U.S. entered the war and bombing raids began to take a heavy toll. The situation in Germany for expanding an oil shale industry during the war was, of course, entirely unique. It was only necessary to issue an order to that effect with no concern for economic viability. Instead of developing

plans similar to those of existing plants, however, the group given the responsibility for oil shale directed their efforts toward in situ recovery. Some technology was developed, but the overall effort was unsuccessful and little shale oil was ever produced.

Meanwhile the Dotternhausen plant was damaged by bombs during the war and operations had ceased. In 1943, Lurgi began construction of an oil shale plant at Frommern but it was never completed. Both of these projects were resurrected after the war and by late 1947 both plants were back in operation with a combined production of 1,500 tons-per-day. The Lurgi plant was equipped with Schweitzer retorts whereas the Dotternhausen plant utilized Meier-Grollman retorts. Both plants were located in the Province of Wurttemberg.

A small-scale industry may still exist in Germany but, ironically, it is for making building materials from spent shale. Oil production is not important. Germany's oil shale deposits are of relatively poor quality which helps explain the erratic nature of the industry there. There is little prospect that oil shale will be important to Germany in the future.

Israel

The Israeli government evaluated Dead Sea shales as a source of power plant fuel in the early 1950's, but found the idea to be uneconomical. Recent interest has been shown in shales found in the Negev desert where more than 600 million tons of reserves have been delineated. The deposit is situated near several industrial operations requiring large amounts of process heat and power. Thus the question is whether to burn the shale directly for production of heat or to retort the shale to yield liquid and gaseous fuels. The Israeli power industry now depends entirely on imported fuel oil, so the prospects for oil shale development are excellent.

Jordan

A thorough exploration program was conducted during the past decade with financial and technical assistance from the U.S. and British governments. An excellent deposit of high grade shale has been identified but political problems have inhibited further development efforts.

Morroco

Interest was shown during the past three or four years in investigating oil shale potential, but the present status is unknown.

New Zealand

The existence of oil shale in New Zealand has been known for several generations. Shale oil was even produced in small quantities from time to time beginning in about 1900, but significant production was never achieved. Studies during the past five years indicate deposits are too small and of low quality.

Peoples Republic of China

A 450-foot thick oil shale deposit overlies one of the world's thickest coal deposits in the vicinity of Fushun in Liaoning Province of Northern China. The oil shale may never have been commercially exploited except for the fact that it exists as overburden which had to be removed anyhow to reach the coal deposit. In any event, the Japanese began commercial utilization of the oil shale at Fushun in 1926. Shale oil was a principal source of liquid fuels for Japan during World War II.

The Fushun industry was in full operation in 1970 with a reported crude shale oil production of 2 million tons annually, from 30 million tons of oil shale. This is the equivalent to some 15 million barrels or about 40,000 barrels per day. At that time, it was believed that coal mining was being shifted to underground operations, which would preclude the need for mining the overburden oil shale and thus jeopardize the shale oil industry. But it was reported in 1974 that China was instead planning to expand shale oil production to as much as 10 million tons annually, or about 200,000 barrels per day. This would require the mining of some 150 million tons of oil shale.

Several large refineries exist near Fushun today and they process conventional petroleum in addition to shale oil. The Fushun retort is said to be at least comparable to any design used elsewhere. One-fifth of China's total requirement for oil products are said to have been met with shale oil in 1974. It is also reported that some shale oil is exported to Japan.

A second Chinese oil shale facility has been reported to be operating near Maoming, in the southern Province of Kwangtun, possibly producing two million tons of oil shale per year. Press releases suggest that these facilities are in working condition and that production is "considerable".

Generally speaking, reliable data on the Chinese operation are scarce.

Romania

A team of government technologists has been studying oil shale prospects for the past five years in an area near the Yugoslav border. Technical assistance has been sought in the U.S., but mining conditions are unfavorable and shale quality relatively poor.

Scotland

The Scottish oil shale industry began around 1860. Sometime shortly after that, more than 140 companies and individuals were engaged in oil shale ventures. The industry, which supplied products for the home, grew and prospered until the decreasing cost of imported petroleum reduced profits. In addition, the advent of synthetic ammonia made the production of ammonium sulfate as an oil shale by-product unprofitable. To survive, many of the small industries were absorbed by larger ones. By 1870 when production had reached 800,000 tons annually, there were some 50 oil shale companies operating. The number was reduced to six by 1910 when production reached 3 million tons annually. Production hit an all-time high in 1913: 3,280,000 tons, or about 4,400 barrels per day. By 1920, all oil shale operations in Great Britain were consolidated under one parent company, Scottish Oil Ltd., which later became a subsidiary of the Anglo-Iranian Oil Co.

The Scottish industry continued at a relatively good pace after that although production gradually decreased. Diesel oil and gasoline were the principal products but tars and waxes were also produced in significant quantities. A good-sized soap plant even operated during the late 1930's and early 1940's. In 1947, 12 mines, 4 retorting plants and a central refinery were in operation, but production by that time had decreased to 1.4 million tons per year. Although the industry did not receive direct government subsidies during this period, a portion of the diesel and gasoline taxes were remitted to the company to encourage production. Nevertheless, the postwar fate of the industry was inevitable. British Petroleum (BP) Company replaced Scottish Oils Ltd. as the oil shale operator in the early 1950's. Production declined sharply and became progressively less profitable. BP conducted some in situ recovery experiments during this period, but with little success. Finally, BP decided in 1964 to suspend oil shale operations, which by that time were not profitable at all. The mines were plugged, and the retorting, transportation, and refining facilities were dismantled and mostly scrapped. The work force, which had numbered 900 in 1962, was disbanded. Today, the only remaining evidence of the Scottish oil shale industry are hills of spent shale - - if you know where to look. Mother Nature has done her job relatively well in revegetating the hills.

The industry's fate still seems sealed. A 1974 study prepared for the British government concluded that oil shale production would still be uneconomical and should not be resumed, but recommended that the situation be closely monitored and that updated geologic exploration be undertaken.

Sicily

Oil shale has never been developed commercially in Sicily. A large deposit of medium grade is indicated, but it has never been thoroughly evaluated.

South Africa

A small deposit of high grade shale at Ermelo was developed commercially in 1935. The reserve was eventually depleted and operations ceased a few years ago. A search for new deposits has been unsuccessful to date.

Spain

Spain's oil shale deposit is relatively small. A small plant built in 1922 by the Penarroya Co. at the country's principal deposit near Puertollano about 120 miles south of Madrid. The Penarroya plant was operated off-and-on for the next 30 years. Production from the plant was never large, perhaps no more than 100 to 200 barrels daily.

The National Industrial Institute of Spain created a new oil shale company in 1942 and development work was begun in the Puertollano area. It probably encompassed the older Penarroya plant or replaced it altogether. In any event, the new plant was referred to as the Calvo Sotelo plant. It was completed in 1955, but its retorts were both outdated and uneconomical. The operations were eventually integrated with a new refinery using imported petroleum. It is doubtful that shale oil is still being produced today.

Sweden

The oil shale deposits in Sweden have been subjected to relatively intensive geologic investigation over the years. They are scattered throughout the country and are small but reasonably good quality reserves. About 1920, an experimental oil shale plant was erected at Kinnekulle with government support. The plant was a technical success but it was later shut down for economic reasons. Nevertheless, the retort used in this operation was an important development and was the basis for later industry developments.

During World War II, Sweden found it necessary again to turn to shale oil production and a much larger plant was built at Kvarntorp, entirely at government expense. The shale deposits at Kvarntorp consist of two layers, each 20 to 25 feet thick. The upper layer yields about 13 gallons of oil per ton and the lower layer yields about 18 gallons of oil per ton, when retorted. Above the shale, there is usually a bed of limestone. An open pit mine was opened at an outcropping of shale and an in situ operation was conducted nearby where a gas-tight limestone capping was present on the shale bed. The original plant included three Bergh retorts, two IM tunnel kilns, one HG retort, a Ljungstrom method in situ operation, condensation equipment, shale quarry, topping plant, refinery, steam power plant, sulfur recovery plant, and tank farm. The plant had a capacity of about 260 barrels daily during the war.

The Ljungstrom in situ method featured electrothermal heating of shale in place. The field was prepared by draining off groundwater and drilling holes for emplacement of heating elements and for oil vapor collection. Holes were arranged in a hexagonal pattern with 7-foot spacings. Electric power came from the company's own steam power plant as well as from public power lines. The heating period lasted for about five months. The shale attained 550°F after three months and 700°F after five months. Shale oil vapors and gases seeped toward the gas vapor wells and reached the condensers under pressure created by the in situ field. By bringing in additional areas, a heat wave was made to pass through the shale at a rate of about 500 feet per year.

The plant was improved after the war and by 1947 was producing shale oil at about 1,600 barrels per day. Post-war economics finally caught up with the plant, however, and shale oil production was phased out in 1963, although the refinery and by-product facilities continued operation on imported oil feedstocks.

Thailand

Studies of Thai oil shale were begun fairly recently by a consortium of Thai, Japanese and U.S. interests. A significant deposit of rich shale is indicated, making the long term outlook reasonably good. But commercial production has never been achieved and there is no active project known to exist today.

USSR

USSR oil shale history is, for the most part, Estonian oil shale history. Estonian oil shale, known as kukersite is among the richest oil shale in the world and sufficient reserves exist for a very large industry. Most kukersite processed by the Soviets exceeds 40 gallons per ton. The two principal uses to date have been as a boiler fuel by simply burning the shale, and as a source of combustible, low-BTU town gas primarily for use in Leningrad. Lately, the Soviets have been directing their R&D efforts towards the production of oil and chemicals.

The history of the Estonian oil shale industry began in 1920, three years after the nation was freed from imperialist Russian rule. Research and development was conducted during the following several years, and in 1925 the State Oil Shale Industry erected a plant with a capacity of 200 tons per day. The Pintsch-type retort installed in the plant was used for production of low-BTU town gas and was no doubt the progenitor of the modern-day gas generator known as the Kiviter retort.

Two years later a company known as the Oil Shale Syndicate built the first tunnel oven. Then, in 1930 and 1931, two tunnel ovens or kilns were built at the Estonian Mineral A-G plant. They each had a capacity of 250 tons. The tunnel kiln results were so encouraging that two more were built in 1936 and 1937, each having a capacity of 400 tons. The tunnel kilns were batch-type processes wherein as many as 18 shallow hopper cars loaded with oil shale to a depth of about one foot would pass through a rectangular-shaped steel tunnel several hundred feet long. Hot gases would be passed through the shale beds and gas and oil recovered. All of the evolved gas and some of the oil was needed to produce heat for the process, so it was relatively inefficient. Even so, tunnel ovens were used until the late 1960's.

The New Consolidated Gold Fields Company started R&D of another process in the late 1920's, including pilot plant work in England. In 1931, it built a plant containing eight externally heated rotary retorts with a combined capacity of 200 tons per day. The Davidson rotary retort (named after its English designer) was the forerunner of the present day Galoter retort and is similar to the TOSCO II retort in that it employed indirect heating of oil shale. Carbon on spent shale was burned to provide retorting heat.

The Estonian oil shale industry was thus well established by the late 1930's. Production reached nearly 800,000 tons in 1938, second only to Scotland. But war was on the way. Estonia was occupied by Russia in 1939. While the existing industry was not severely hampered, any expansion plans were likely curtailed. In 1941, Germany invaded Estonia and the Russians disabled the entire industry as they withdrew to the east. The Germans immediately developed plans to restore the industry using local materials and to greatly expand it using plants designed and fabricated in Germany. They never had a chance to get started. Russia regained possession of Estonia in 1944. They apparently assumed the German plans for expanding the oil shale industry also. The Russian five-year program called for 9.4 million tons of production annually. That goal was probably not reached; however, at least one new plant was completed during the 1950's.

During the 1960's, an impressively large R&D program was carried out to develop the Kiviter and Galoter processes. Two large demonstration plants (1,000 Tpd) were built in the early 1970's and are still being operated today. Even larger retorts are being designed and may now be under construction. Licensing of the Kiviter and Galoter is now being pursued in the U.S. through the Soviet Licensitorg. Resource Sciences Corporation of Tulsa has played a role in this effort.

The old rotary retorts and tunnel ovens were phased out before 1970, but 1971 production in Estonia was estimated at 18.1 million tons, or about 50,000 tons per day. Some confusion exists over current production. One source reported in 1976 that production had reached 54 million tons annually. Then in 1977, the *Oil & Gas Journal* reported that 50 to 60 million tons annually is the goal by the end of the decade. The latter report seems more believable.

The principal use of Estonia kukersite today is as a fuel burned directly in electric power generation. While shale production in Estonia

represents only about one percent of total USSR fuel requirements, it accounts for some 90 percent of Estonian power production. Two-thirds of all oil shale mined in Estonia is burned directly in power plants; the remainder is processed to obtain fuel oil, gasoline, town gas primarily for Leningrad, and various chemicals.

Another oil shale area in the USSR thought to be receiving some attention is the lower Volga region. There probably was some development there during the 1930's and it may even have approached the size of the Estonian industry at one time. During recent conversations with Soviet technologists, however, this region was not mentioned.

Zaire

Production of oil shale in Zaire has never been achieved and recent attempts at exploration and evaluation of deposits have been interrupted by political events. However, reserves of high grade oil shale are indicated to be large.

Appendix B

ABBREVIATIONS

DOE	Department of Energy
DRI	Denver Research Institute
EMSL-RTP	Environmental Monitoring and Support Laboratory, Research Triangle Park, North Carolina
EPA	Environmental Protection Agency
ERDA	Environmental Research and Development Administration
ERL-Athens	Environmental Research Laboratory, Athens, Georgia
ERL-Gulf Breeze	Environmental Research Laboratory, Gulf Breeze, Florida
FY	Fiscal Year
HERL-RTP	Health Effects Research Laboratory, Research Triangle Park, North Carolina
IERL-CIN	Industrial and Environmental Research Laboratory, Cincinnati, Ohio
IERL-RTP	Industrial and Environmental Research Laboratory, Research Triangle Park, North Carolina
LASL	Los Alamos Scientific Laboratory, Los Alamos, New Mexico - (Under the DOE)
LERC	Laramie Energy Research Center, Laramie, Wyoming - (Under the DOE)
LLL	Lawrence Livermore Laboratory, Livermore, California - (Under the DOE)
NBS	National Bureau of Standards
NIOSH	National Institute of Occupational Safety and Health
OEMI	Office of Energy, Minerals and Industry
OER	Office of Energy Research
ORD	Office of Research and Development
ORNL	Oak Ridge National Laboratory, Oak Ridge, Tennessee - (Under the DOE)
R&D	Research and Development
TOSCO	The Oil Shale Corporation
UCLA	University of California at Los Angeles
USBM	U.S. Bureau of Mines
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

Appendix C

GLOSSARY

ATP - Adenosine triphosphate; acid that occurs in living cells which plays a role in releasing available energy for the work of muscular contraction, and that plays a vital role in most other biochemical processes that either produce or require energy.

Auxotroph - A mutant strain of an organism that requires some growth factor.

Azaguanine - 8-azaguanine; guanine in which the -CH=group in position 8 is replaced by -N=. It interferes with the growth of certain mouse tumors, possibly because a nucleic acid containing 8-azaguanine functions as an antimetabolite for a corresponding nucleic acid containing guanine.

Bioassay - Determination of the relative effective strength of a substance by comparing its effect on a test organism with that of a standard preparation.

Carcinogenesis - The production of cancer.

Carcinogenic - Producing or tending to produce cancer.

Cilia - Relatively short, centriole-based, hairlike, processes on certain anatomical cells and motile organisms.

Columnar cells - An epithelial cell in which the height is markedly greater than the width.

Cytochemistry - The science concerned with the chemistry of cells and cell components, primarily with the location of chemical constitutents and enzymes.

Cytological - Of or relating to methods of cytology.

Cytology - A branch of the biological sciences which deals with the structure, behavior, growth, and reproduction of cells and the function and chemistry of cell components.

Cytoplasm - The substance of a cell exclusive of the nucleus.

Cytotoxin - A specific substance, usually with reference to antibody, that inhibits or prevents the functions of cells, or causes the destruction of cells, or both.

DNA - Deoxyribonucleic acid; any of various nucleic acids that yield deoxyribose as one product of hydrolysis, are found in nuclei and genes, and are associated with the transmission of genetic information.

Electrophoresis - The migration of charged colloidal particles through the medium in which they are dispersed, when placed under the influence of an applied electric potential.

Enzyme - A catalytic substance, protein in nature, formed by living cells and having a specific action in promoting chemical change.

Epithelium - A cellular animal tissue that covers a free surface or lines a tube or cavity, that consists of one or more layers of cells forming a sheet practically unbroken by intercellular substance and, either smoothly extended, or much folded on a basement membrane and compacted, and serves to enclose and protect other parts of the body.

Esterase - Any of a group of enzymes that catalyze the synthesis and hydrolysis of esters which are a compound formed by the elimination of water and the bonding of an alcohol and an organic acid.

Eucaryote - A cell with a definitive nucleus.

Fibroblast - A stellate connective tissue cell found in fibrous tissue. Also known as fibrocyte.

Guanine - A purine base important mainly as a component of ribonucleic and deoxyribonucleic acids.

In Vitro - Pertaining to a biological reaction taking place in an artificial apparatus.

In Vivo - Pertaining to a biological reaction taking place in a living cell or organism.

Karotype - The chromosome characteristic of an individual or a cell line.

Leukocyte - Any one of the white blood cells.

Lidar - An instrument in which a ruby laser generates intense infrared pulses in beam widths as small as 30 seconds of arc; scattering of clouds, smog layers, and some atmospheric discontinuities are measured.

Lymphocyte - An agranular leukocyte formed primarily in lymphoid tissue.

Macrophages - A large phagocyte of the reticuloendothelial system.

Mutagen - An agent that raises the frequency of mutation above the spontaneous rate.

Neoplasm - New growth; an abnormal tissue that grows by cellular proliferation more rapidly than normal and continues to grow after the stimuli that initiated the new growth cease.

Ouabain - White crystals that melt with decomposition at 190°C, soluble in water and ethanol.

Periphyton - Sessile biotal components of a freshwater ecosystem.

Phenotype - The sum total of visible traits which characterize the members of a group.

Phytoplankton - Passively floating or weakly motile aquatic plants and animals.

Procaryote - A microorganismal cell that lacks a mitochondria; its genome consists of a large molecule of DNA not enclosed within a membrane, and does not undergo mitosis during replication.

Raman Band - Band observed in the scattering of light as it passes through a change in frequency and a random alteration in phase due to a change in rotational or vibrational energy of the scattering molecules.

RNA - Ribonucleic acid; a long chain, usually single-stranded nucleic acid consisting of repeating nucleotide units containing four kinds of heterocyclic, organic bases; they are conjugated to the pentose sugar ribose and held in sequence by phosphodiester bonds; involved intercellularly in protein synthesis.

Teratogen - An agent causing formation of a congenital anomaly or monstrosity.

Thiophene - A heterocyclic constituent of coal tar; used as a solvent and in the manufacture of medicinal agents.

Appendix D

GENERAL REFERENCES ON OIL SHALE

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Appendix E

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The following reports were published before October 1977.

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EPA-600/9-77-033	NA***	"Oil Shale and the Environment," EPA Decision Series (October 1977)
EPA-625/9-77-002	NA	"Environmental Sampling of the Paraho Oil Shale Retort Process at Anvil Points," Executive Briefing, EPA Technology Transfer Series (October 1977)
EPA-908/4-77-010a&b	NA	"Emissions from Synthetic Fuels Production Facilities," Radian Corporation (September 1977)
EPA-600/7-77-069	NA	"A Preliminary Assessment of Environmental Impacts from Oil Shale Development," TRW/DRI (July 1977)
EPA-600/7-77-072	NA	"Energy from the West: A Progress Report of a Technology Assessment of Western Energy Resource Development," 3 Vol. University of Oklahoma, Radian Corporation (July 1977)
EPA-908/4-77-007	NA	"Oil Shale Research Overview," Cameron Engineers (May 1977)
EPA-600/7-77-032	NA	"Interagency Energy/Environment R&D Program-Status Report III," OEMI (April 1977)
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EPA-600/7-77-024	PB-266-256/7BE	"Western Energy/Environment Monitoring Study: Planning and Coordination Summary," EPA/OEMI (March 1977)

* Available through U.S. EPA, National Environment Research Center, Research Triangle Park, North Carolina 27711, (919) 549-8411.

** Available through the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22151, (703) 321-8654.

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EPA-TR-76-74	PB-259-070-T/BE	"Some Data on the Composition of Neutral Oxygen Compounds of Estonian Shale Resins which Boil Under 200°C," USSR (1972)
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